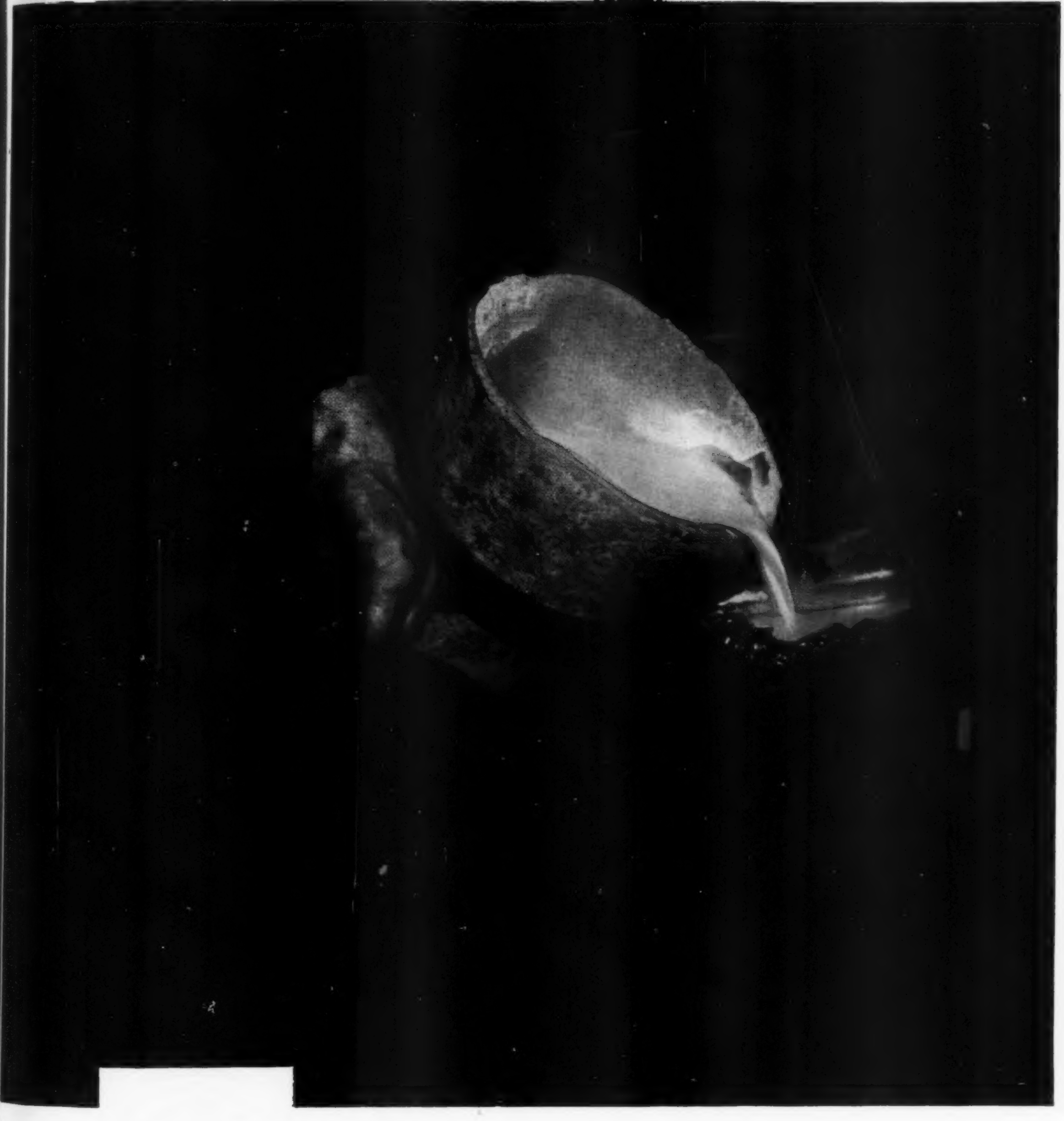
METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 57 No. 344 JUNE, 1958 Monthly: Two Shillings and Sixpence



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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR JUNE, 1958 Vol. 57 No. 344

PUBLISHED MONTHLY BY
The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.
Telephone: BLAckfriars 2084

London Office:
158, Temple Chambers,
Temple Avenue, E.C.4.
FLEet Street 8914

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Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

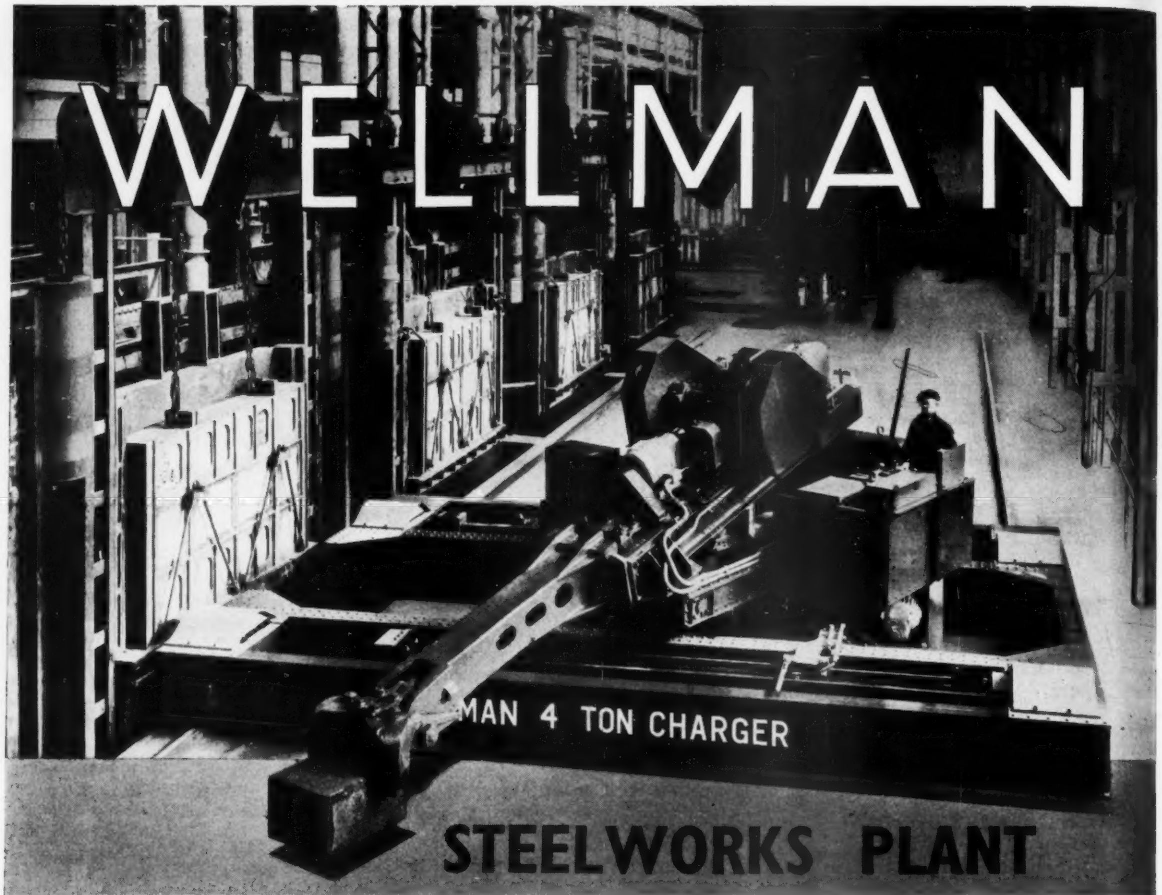
SUBSCRIPTIONS

Subscription Rates throughout the World—30/- per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

The articles in this Journal are indexed in THE INDUSTRIAL ARTS INDEX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The Sky's the Limit

WHETHER or not the metallurgist is taking his rightful place in the scheme of things was one of the topics discussed by Mr. W. E. Ballard in his recent Presidential Address to the Institution of Metallurgists, and in view of its interest to many outside his immediate audience, reference is made here to a number of the President's observations.

It is impossible, when considering questions such as this, to be dogmatic, but whilst many members of the Institution occupy high positions, it does appear that the proportion of metallurgists who do so is less than it should be. Younger members complain that—whether they are employed by an industrial firm, a research organisation, or a government department—there is a lack of opportunity, the most important posts being held by administrators, accountants and the like. On the other hand, many older members in positions of authority, whilst admitting freely that young men entering the profession today are highly trained as far as scientific knowledge is concerned, stress that too often they appear to lack the ability to make decisions and take responsibility. Some too, find it difficult to express themselves adequately in public speaking, or even in writing.

It is often suggested that the fault lies with the educational system, but hopes that a solution of educational problems will be found in our lifetime are not heightened by the lack of progress in the last two thousand years, as may be seen from the following quotation from Aristotles' "Politics," which could have been written today. "We must not leave out of sight the nature of education and the proper means of imparting it, for at present there is practical dissension on this point; people do not agree on the subjects which the young should learn, whether they take virtue in the abstract or in the best life as the end to be sought, and it is uncertain whether education be properly divided rather to the cultivation of the intellect or moral discipline. The question is complicated if we look at the education of this day, nobody knows whether the young should be trained at such studies as are useful as a means of livelihood, or in such as tend to the promotion of virtue in the higher studies."

Many members of the Institution would like to see a wider basis for the studies of those aspiring to be metallurgists. A grounding in mathematics, chemistry and physics is now insisted upon, but they advocate also, in the early years, some teaching of the humanities. There is, for instance, a good deal to be said for an acquaintance with history, for as Livy the historian of Rome wrote: "The study of history is particularly salutary and fruitful, because in it you can see, in a brilliant record, illustrations of every possible type, and from it you can take for yourself and your state examples to imitate, and others, disgraceful in their origin and issue, to avoid."

If evasion of responsibility does exist, is it because, owing to the nature of their study of metals, students have been forced to give less time to the more important theme of learning about their fellow men? To many people the success of the older universities is not so much due to the subjects taught and the way they are taught, as to the fact that students from different faculties have greater opportunities for meeting and discussing life in all its aspects.

At the other end of the educational scale is the entry into metallurgy, particularly ferrous metallurgy, by way of the shift system, first in the laboratory and then on the shop floor. One of the essential features of the system is the acceptance of responsibility, for no plant manager likes to be awakened from his slumbers every night. Additionally, it develops an appreciation of the old hands who know how to do the job, if not the reasons why they achieve results. The fact that this method of entry is now somewhat despised fits in with the belief that today the study of human beings does not get the emphasis it deserves.

In the metallurgical industries, there are usually three streams of recruitment to executive positions. The first, the administrative professions—sales and accountancy; the second, engineering or production; and the third, development and research, including metallurgy. There is a danger that the individual in the third stream tends to be furthest away from humanity, and hence is likely to be lacking in confidence, for only by contact with others can full development take place. Wide reading in itself is not enough, it must be accompanied by personal contact with other human beings. Human relations of this type cannot be learned from books or by instruction; they can only be learned in practice; and the study of the behaviour of the workman and that of his colleagues will tend to give the metallurgist an understanding not only of them, but also of those in authority, for human motives are almost universally similar.

Not all metallurgists have a yearning to become administrators or directors—in fact, many would rather not—but those who do will not be able to take their rightful place unless they are able to sell themselves, unless they have the confidence to make decisions and to question, where necessary, the opinions of their superiors. It has been suggested that a scientist cannot understand men or commerce, and therefore is not a good business man. That this is completely untrue is shown by the growing number of scientists and technologists on the boards of both private and public companies, but the fiction persists.

Mr. Ballard concluded with advice to younger members to take every opportunity of studying people; to be willing to learn from the lowliest; and to develop themselves as individuals; and with a plea to older members to give the juniors the opportunity to mix with their colleagues and, if possible, in business, with customers and suppliers.

Research Council Report

THE Report of the Council for Scientific and Industrial Research for the year 1956–57* is the first report of the new executive council established under the D.S.I.R. Act, 1956. It begins with a review of the great changes that have taken place in industrial and scientific research since the Department was set up forty-two years ago, which is followed by a consideration of the effect that these changes may have had on the fundamental tasks of the Department.

The universities are, and will continue to be, the main centres of pure research, though a proportion of pure research should be carried out wherever applied research is done on any scale. Care must be taken to ensure that full use is made of the potential research capacity of university staff. The Department has an important role to play here, and the Council believes that its expenditure on this activity must rise considerably. In 1956/57, the Council recommended 115 grants for special research projects in science and technology, totalling £836,000 in value, compared with 47, totalling £400,000 in the previous year.

The Council is reviewing the role of D.S.I.R. Stations in research of direct application to industry, but this review will take some time to complete. The investigations have covered a considerable part of the field, and the Council states that there is a large and growing field of activity in which the Government has a direct interest and a special responsibility, and in which, therefore, the research work required is appropriate to a national research establishment. In order to undertake new responsibilities, however, it is necessary to shed some of the existing load.

The action already taken as a result of the review includes the handing over of responsibility for some sections of the work of the Department's Forest Products Research Laboratory to the Timber Development Association, which receives a grant from the Department. Another step is the proposal that the Agricultural Research Council should take over responsibility for the Low Temperature Research Station, Cambridge, and the Ditton Laboratory, East Malling, from the Food Investigation Organisation: this is being considered by the Agricultural Research Council. A further step which has been taken is to arrange that the Fuel Research Station will be closed early in 1959. Such of its work as is to be continued will be transferred to the new station at Stevenage, which will have much wider scope and facilities for process development. Details have already been made public. *Ad hoc* committees have also been set up by the Council to review the work and functions of three other D.S.I.R. Stations—the National Physical Laboratory, the Chemical Research Laboratory and the Mechanical Engineering Research Laboratory—and some changes at the N.P.L. have already been announced.

One of the questions facing the Council is the perennial one of all research authorities: "given the growing need for expensive team work, how should resources be allocated to avoid spreading them over too wide a field?" On this point, the Council expresses grave doubt of the adequacy of the resources for all that it is charged to do. It points out that in those industries that do not benefit directly from research done primarily for defence purposes, the value of production approaches £10,000 million a year. By contrast, the Department is spending less than £10 million a year for *all* its activities. Finally the Council has under review the extent to which industries served by the grant-aided Research Associations can be expected to shoulder the whole financial burden of an adequate research programme, either now or in the near future? Whatever the financial arrangements ultimately made, the Council firmly believes that the nation's research effort must be increased and that the Department has a large part to play.

* The Report of the Research Council of the Department of Scientific and Industrial Research is a Command Paper (Cmnd. 428), published by H. M. Stationery Office, price 4s. (72 cents U.S.A.) by post 4s. 4d.

Novel Use for Liquid Nitrogen

DURING the hot-dip galvanising process in the wire drawing industry, wire is drawn through a bath of molten zinc. When this bath or kettle becomes overheated, the zinc tends to attack the kettle surface and there is a risk of bursting and consequent leakage of the metal. The amount of zinc resulting from this leakage, known as a spill, can be quite large if the leak is not plugged quickly, and since it is a ductile metal, it is difficult to break the spill by normal methods.

One answer to the problem, however, is to freeze the spill with liquid nitrogen. This has the effect of rendering the metal brittle and it can then be broken up by means of a sledgehammer. Messrs. John Rigby & Sons, Ltd., the Bradford wire manufacturers, sought the advice of British Oxygen Gases, Ltd., recently when they were confronted with a spill weighing 10 tons. Liquid nitrogen was poured from a tanker on to the surface of the spill, gradually working from the outer surface to the centre. In this way, the mass of zinc was reduced to small sections with comparative ease.

When work of this nature is carried out in a confined space, precautions must be taken to ensure that operators do not inhale too much nitrogen gas. It must also be borne in mind that the surface of the zinc becomes extremely cold following the application of liquid nitrogen and can cause permanent damage if it is allowed to contact the skin.

This method of the reduction of scrap by extreme cold may well be applied in other industries to other normally ductile metals which have to be broken up.

Tonnage Oxygen for Gas Industry

THE North Western Gas Board will be the first Gas Board in this country to install a tonnage oxygen plant. It will be installed in the new hydrogenation plant at Partington, near Manchester, and will be capable of producing nearly 63 tons of oxygen per day. The oxygen will be used for the partial oxidation of oil for the purpose of producing hydrogen, which will be used to hydrogenate further quantities of oil in order to produce town's gas. Later, coal will be used as the raw material.

High standards of operating efficiency are necessary for a plant of this type. The contract for it was placed with Air Products (Great Britain), Ltd., by Humphreys and Glasgow, Ltd., who are the main contractors. One of the major factors considered in the adoption of the Air Products tonnage oxygen plant was the oxygen compression system, which features liquid oxygen pumps for delivering the oxygen under pressure. This system dispenses with the need for stand-by gas holders, and ensures the delivery of oxygen at constant pressure, and consistent purity and flow. These conditions are essential for the efficient operation of the partial oxidation plant.

A Review of Diffusion in Aluminium

By J. W. H. Clare, B.Sc.,

Aluminium Laboratories Limited, Banbury, Oxon.

The published data on diffusion in aluminium alloys have been collected together and presented so that direct comparison and easy assessment are possible. The most likely sources of error introduced during the experimental work are discussed.

DIFFUSION plays an important part in many metallurgical processes; almost all phase changes in alloy systems involve a redistribution of the constituent atoms, and so are dependent on diffusion phenomena. For example, age hardening, compound formation, recovery and recrystallisation are all phenomena where a knowledge of the movement of solute elements is required before the processes may be completely explained.

Diffusion is a statistical effect which depends entirely upon the relative movement and concentration of the atoms constituting the system. From the simple consideration of an alloy containing a concentration gradient, which during diffusion will tend towards a uniform distribution, the basic laws governing the diffusion process may be derived. These simply indicate that there is always a positive flow of atoms down the concentration gradient, and that the flow is proportional to the concentration gradient. A proportionality factor D is introduced which is known as the coefficient of diffusion. This is defined as the amount of substance diffusing in unit time across unit area through a unit concentration gradient, and is generally expressed in sq. cm./sec.

The diffusion coefficient increases with increase of temperature according to the Arrhenius relation

$$D = De_0{}^{-Q/RT}$$

where D_0 = diffusion constant
Q = activation energy for diffusion expressed in cal./g.-atom
R = gas constant expressed in cal./g.-atom/degree
T = absolute temperature.

Much of the work on diffusion has been centred on this equation.

The results for the diffusion of solute elements in aluminium are presented in the form of graphs of log D against $1/T$, ignoring any variation of D with concentration, or of D against concentration for fixed temperatures.

Excellent reviews of the general subject of diffusion in metals have already been published by Le Claire.[1, 2] The present review is an appraisal of the available information on diffusion in aluminium and discusses the reliability of the published work, taking into account the errors introduced by the experimental methods.

Self-Diffusion

The self-diffusion of aluminium has not yet been measured experimentally; this lack of data has been due to the short half-lives of the common aluminium isotopes. Quite recently a long-lived aluminium isotope has been reported,[3, 4] but this has not yet been used to obtain an experimental value of the diffusion coefficient.

Two theoretical values have been proposed; Le Claire,[5] assuming a vacancy mechanism and a number of constants averaged for cubic metals, suggests

$$D = 0{\cdot}72\ e^{-42{,}000/RT} \text{ sq. cm./sec.}$$

whilst Nowick[6] suggests

$$D = 0{\cdot}45\ e^{-33{,}000/RT} \text{ sq. cm./sec.}$$

as a result of calculations for a number of pure metals and their alloys. Kê[7] estimates the activation energy to be 37,500 cal./g.-atom on the basis of binding energy and melting point, this value being based on an empirical rule for face-centred cubic metals proposed by Johnson[8].

It was suggested by Seymore[9] that results he obtained from nuclear magnetic resonance measurements in aluminium might lead to a measure of self-diffusion. His calculations gave the following diffusion coefficient:

$$D = 10^{-3}\ e^{-21{,}000/RT} \text{ sq. cm./sec.}$$

which is so far from the expected values that some error is thought to be present in the theoretical application of his results.

Kuczynski[10] has suggested that his method, used successfully with copper and silver, might be applied to aluminium. This method requires a former of the pure material around which is wound a thin wire of the same material. The specimen thus formed is annealed in the usual way before being metallographically mounted and polished. The width of the adhesion between the former and the wire is measured at several places and from the average width the coefficient of self-diffusion is calculated. The validity of the results obtained has been questioned[2]; one of the main objections is that the calculation depends on a term involving the fifth power of the adhesion width. This width will be small and any slight error in measurement becomes large when substituted in the equation deduced by Kuczynski. However, in view of the fact that no other method is capable, at present, of producing a value for the self-diffusion of aluminium, it might be useful to undertake some experiments using this method and accept the experimental and theoretical limitations.

Diffusion of Solute Elements in Aluminium

A study of diffusion of solute elements in aluminium is complicated by the tenacious oxide film present on the surface of the metal, and also by the limited solid solubilities of added elements. Diffusion studies necessitate as clean an interface as possible, so that nothing can act as a barrier to the transfer of atoms. It is also important to be able to carry out an accurate analysis for the solute metal, so as to give a smooth concentration-distance curve. Thus, it is not surprising that most of the practical diffusion studies have been made on binary systems, not based on aluminium, in

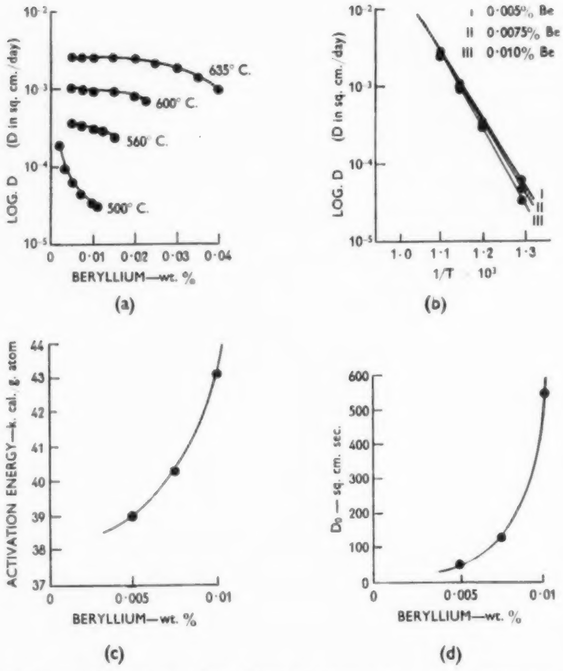

Fig. 1.—Diffusion of beryllium in aluminium : (a) diffusion coefficient D as a function of temperature and concentration (Bückle and Descamps[11]); (b) curves of log Dv. 1/T sections for three concentration values taken from (a) (Bückle and Descamps[11]) ; (c) activation energy v. concentration curve from the results in (b) ; (d) diffusion constant v. concentration curve from the results in (b).

which the two component metals have complete solid solubility in each other, making precision analysis unnecessary. In the limited solid solutions of aluminium alloys, the curve must be completed in such a narrow concentration range that one of the most sensitive parts of the curve appears at extremely low concentrations, and accurate analysis of such low concentrations is not possible by ordinary methods.

The methods of specimen preparation which have been used for diffusion studies of solute elements in aluminium are shown in Table I(*a*). Of the methods listed, not one completely eliminates oxide at the interface, although rolling appears to be the most favourable, as the original surface oxide present before rolling is broken up and is distributed over a very much larger area during the rolling process. Provided that the broken particles are finely dispersed, they play no major role in diffusion processes. The disadvantage of rolling is that during preheating prior to rolling some diffusion may occur, and this must be allowed for in subsequent calculations. The remaining methods do not remove the oxide surface, and are therefore liable to some errors, the extent of which is unknown, as a direct comparison has not been carried out.

The methods previously used to measure the variation of concentration with distance in aluminium alloys are shown in Table II. The major difficulty met in aluminium alloys has already been mentioned—measurement of the small concentration differences present in aluminium solid solutions. It is not surprising, therefore, to find that very few of the diffusion data published for aluminium alloys can be considered reliable. The diffusion coefficient generally varies with concentration, and to detect such a variation it is necessary to get an accurate curve of concentration against distance, and from this obtain several values of the diffusion coefficient for specific values of concentration. Most of the published work on diffusion in aluminium was carried out in the knowledge that the analytical techniques adopted were relatively insensitive at low solute concentrations. Many workers realised that their results indicated that the diffusion coefficient varied with concentration, but their work was too limited to take this into full consideration, and they therefore resorted to giving average values which, in some cases, are operative over a considerable concentration range.

Table III records collectively the previous quantitative work on diffusion of solute elements in aluminium.[11-22] It has been assembled so that it is easy to assess the reliability of the work from the point of view of metal purity and experimental methods. In addition, direct comparison between different workers and different elements is possible. Throughout Table III there are numerous references to Figs. 1, 2 and 3, which reproduce work showing the concentration dependence of the diffusion coefficient, and these results must be considered the more reliable.

Table IV shows the results of published work in which the effect of impurity elements on the diffusion of another element has been investigated.[17, 19] The rate of diffusion of magnesium is seen to be slowed down quite con-

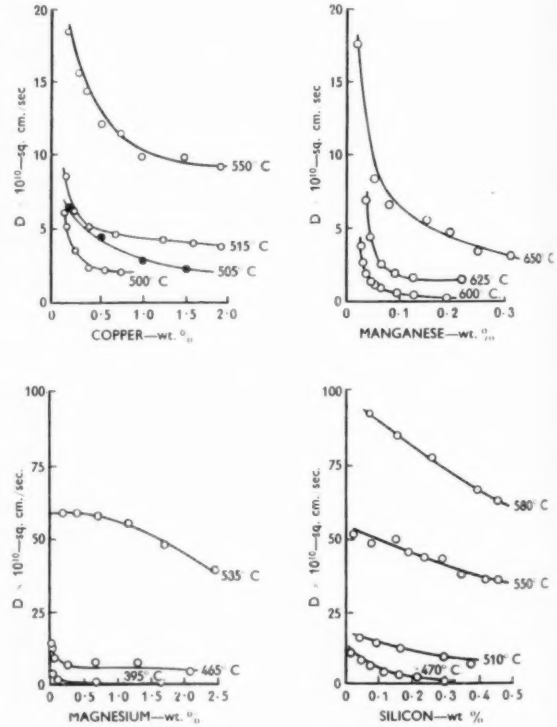

Fig. 2.—Comparison of diffusion coefficient with concentration. All results are due to Bückle,[14] with the exception of the curve at 505° C. indicated by solid circles in the top left set of curves, which is due to Bückle and Keil.[15]

siderably by the presence of zinc, and to fall off rapidly when excess silicon is present.

A number of workers [24-30] have qualitatively studied diffusion in commercially clad materials. Here the emphasis has been on establishing conditions during heat treatment which will avoid diffusion of an element from the core to the outer surface, with subsequent reduction of the good corrosion resistance given to the sheet by the cladding.

Discussion

The results quoted in Table III and Figs. 1, 2 and 3 for the diffusion of a particular element in aluminium show considerable differences from one worker to another. Assuming that the temperature control throughout the diffusion anneal is satisfactory, the following factors would explain the differences :—

(1) method of specimen preparation
(2) method of specimen analysis
(3) method of specimen sectioning
(4) purity of materials.

Specimen preparation can affect the results in three ways. In the first case, unless the surface oxide is removed or broken up during preparation, an oxide barrier which will most certainly affect diffusion rates will be present at the interface. Secondly, any cold work imparted to the specimen will speed up diffusion due to the creation of vacancies, and so provide greater opportunity for atom movements by atom-vacancy exchange. Thirdly, the quality of the interface is of great importance, as any planar variations will lead to incorrect values of the diffusion coefficient. In simple clamping, flat machined surfaces are used, which remain plane ; the interface of a rolled specimen is generally slightly wavy ; and a molten metal interface would appear to be markedly subject to prior diffusion. Table I(*b*) shows an estimate of how these effects may influence the results obtained from the different methods of specimen preparation. It may be concluded from this that specimens produced by rolling should lead to a fairly reliable assessment of the diffusion rate.

Specimen analysis is a very difficult problem to assess, but methods III and V (see Table II) may be immediately classed as doubtful due to the inherent difficulties of the methods. Methods I and II are both direct determinations of a concentration gradient, but accurate analysis of small concentrations in aluminium is difficult and, unless supplemented by a careful estimate of the reliability limits at all levels of concentration, the results

TABLE I.—METHODS USED TO PRODUCE ALUMINIUM ALLOY INTERFACES, AND THEIR SUBSEQUENT EFFECTS ON THE RESULTS.

	(*a*) Method	(*b*) Cold Work Effect	Oxide Effect	Quality of Interface
A	Clamped	c	c	a
B	Rolled	b	a	b
C	Immersion of aluminium in molten alloy	a	a	c
D	Insertion of a core of alloy into an aluminium cylinder closed with a stopper of aluminium	c	c	a

Key : a—no effect—good.
b—some effect.
c—full effect—poor.

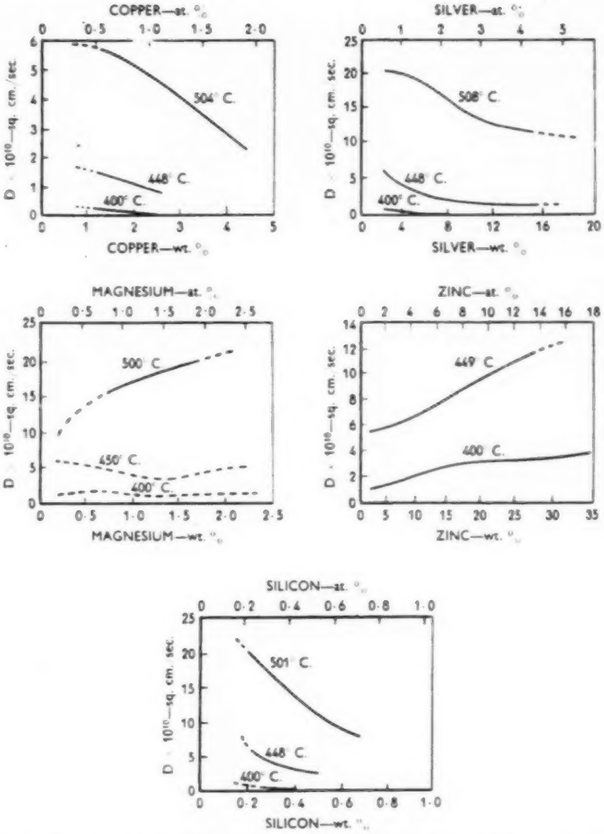

Fig. 3.—Variation of the diffusion coefficient with concentration at various temperatures in aluminium alloys (after Mehl, Rhines and von den Steinen[16]).

obtained will be of little significance. This estimation does not appear to have been carried out by any of the workers. Method IV incorporates an indirect determination, which would be ideal if it were not for the fact that a concentration-hardness calibration curve is required, and this naturally suffers from the same difficulties as methods I and II.

Specimen sectioning is again an important factor when assessing the results. The usual method, that of removing slices, is very much dependent upon the individual worker, as a slight misorientation will lead to errors. It must be assumed that every possible care was taken to remove slices parallel to the original interface.

It has been shown[17, 19] that the presence of certain

TABLE II.—METHODS USED TO PRODUCE CONCENTRATION-DISTANCE CURVES.

	Method
I	Direct determination of concentration gradient in different samples by removal of thin layers and subsequent chemical analysis.
II	As I, but spectrographic analysis instead of chemical analysis.
III	Indirect determination of concentration gradient by studying the appearance of a second phase after diffusion.
IV	Indirect determination of concentration gradient by metallographic sectioning followed by a microhardness traverse across the interface.
V	Evaporation of a volatile solute from surface of specimen.

TABLE III.—DIFFUSION OF SOLUTE ELEMENTS IN ALUMINIUM.

Diffusing Element	Author(s)	Experimental Methods Used (See Tables I and II)	Purity of Aluminium Used	Initial Concentration of Core (wt %)	Temperature (° C.)	D (sq. cm./sec.	Applicable Concentration Level (wt %)	D_o (sq. cm./sec.)	Activation Energy, Q (k. cal./g.-atom)
Beryllium ..	Bückle and Descamps[11]	B. IV	99·998	1·06	500 560 600 635	See Fig. 1a and b	0·005 0·0075 0·010	52 126 550	39·0 40·3 43·1
Copper ..	Beerwald[12]	A. II	99·998	2 0·4	457 497 515 565 565	$0·85 \times 10^{-10}$ $2·5 \times 10^{-10}$ $5·1 \times 10^{-10}$ $14·0 \times 10^{-10}$ $13·0 \times 10^{-10}$	—	0·084	32·6
	Brick and Phillips[13]	C. III	pure Al.	Eutectic	440 490 540	$0·57 \times 10^{-10}$ $2·4 \times 10^{-10}$ $14·0 \times 10^{-10}$	—	—	31·5‡ — 31·4‡ 34·9 31·4‡ —
	Bückle[14]	A. IV	99·998	4	500 515 550	See Fig. 2		—	41·9†
	Bückle and Keil[15]	B. II and IV	pure Al.	5·2	505	$6·7 \times 10^{-10}$ $4·6 \times 10^{-10}$ $2·9 \times 10^{-10}$ $2·3 \times 10^{-10}$	0·2 0·5 1·0 1·5	—	—
	Mehl, Rhines and von den Steinen[16]	B. I and II	99·98	6·96	400 448 504	See Fig. 3		—	33·9*
Magnesium ..	Beerwald[12]	A. II	99·998	10 6 5	395 395 413 447 511 514 577	$0·68 \times 10^{-10}$ $0·56 \times 10^{-10}$ $1·2 \times 10^{-10}$ $2·6 \times 10^{-10}$ $14·0 \times 10^{-10}$ $15·0 \times 10^{-10}$ $44·0 \times 10^{-10}$	—	0·118	28·6 29·6‡
	Brick and Phillips[13]	D. III	pure Al.	Eutectic	365 400 440	$0·11 \times 10^{-10}$ $0·64 \times 10^{-10}$ $3·2 \times 10^{-10}$	—	—	30·3‡ — 29·6‡ 38·5 29·0‡ —
	Bückle[14]	A. IV	99·998	7·0	395 465 535	See Fig. 2		—	26·79†
	Bungardt and Bollenrath[17]	D. I	99·5	98·3 Mg 4·77 4·94 and 7·20	420 475 480 500 520	$0·77 \times 10^{-10}$ $7·3 \times 10^{-10}$ $8·5 \times 10^{-10}$ $22·0 \times 10^{-10}$ $87·0 \times 10^{-10}$	—	—	38·0
	Bungardt and Cornelius[18]	D. I	99·9987 99·5 99·0	14·3	410	$0·60 \times 10^{-10}$ $0·70 \times 10^{-10}$ $0·66 \times 10^{-10}$	—	—	31·0‡
	Freche[19]	B. II	99·985	1·21	450	$19·0 \times 10^{-10}$	—	—	—
	Mehl, Rhines and von den Steinen[16]	B. I and II	99·98	2·49	400 450 500	See Fig. 3		—	32·2*
Manganese ..	Bückle[14]	A. IV	99·998	1	600 625 650	See Fig. 2		—	79·3†
Silicon ..	Beerwald[12]	A. II	99·998	0·52	465 500 509 537 600	$3·4 \times 10^{-10}$ $9·8 \times 10^{-10}$ $18·0 \times 10^{-10}$ $24·0 \times 10^{-10}$ $93·0 \times 10^{-10}$	—	0·90	30·55
	Bückle[14]	A. IV	99·998	1	470 510 550 580	See Fig. 2		—	31·87†
	Freche[19]	B. II	99·985	1·875	510	$20·0 \times 10^{-10}$	—	—	—
	Mehl, Rhines and von den Steinen[16]	B. I and II	99·98	2·54	400 448 501	See Fig. 3		—	31·5*
Silver	Beerwald[12]	A. II	99·998	5	465 467 500 530 573	$1·9 \times 10^{-10}$ $2·3 \times 10^{-10}$ $7·3 \times 10^{-10}$ $11·6 \times 10^{-10}$ $35·0 \times 10^{-10}$	—	1·104	32·6
	Finkelstein and Yamshchikova[20]	—	—	16·5 8·6	525–600 490–580	— —	— —	43·5 29·7	39·0 37·0
	Mehl, Rhines and von den Steinen[16]	B. I and II	99·98	10·28 and 19·82	400 448 508	See Fig. 3		—	38·5*
Sodium ..	Ransley and Neufeld[21]	C. V and I	99·996+	0·002	550 600 625 635 645 650	$6–20 \times 10^{-10}$ 110×10^{-10} $100–300 \times 10^{-10}$ $600–700 \times 10^{-10}$ $300–800 \times 10^{-10}$ $600–900 \times 10^{-10}$	—	—	32·0 29·5‡
Uranium ..	Bierlein and Green[22]	D. —	—	U	200 250 390	$1·3 \times 10^{-10}$ $9·0 \times 10^{-10}$ $110·0 \times 10^{-10}$	—	—	14·3‡

TABLE III.—DIFFUSION OF SOLUTE ELEMENTS IN ALUMINIUM.—(*Continued*)

Diffusing Element	Author(s)	Experimental Methods Used (See Tables I and II)	Purity of Aluminium Used	Initial Concentration of Core (wt %)	Temperature (° C.)	D (sq. cm./sec.)	Applicable Concentration Level (wt %)	D_o (sq. cm./sec.)	Activation Energy, Q (k. cal./g.-atom)
Zinc	Beerwald[13]	A. II	99·998	2	415 450 473 507 555	$2·4 \times 10^{-10}$ $4·0 \times 10^{-10}$ $5·3 \times 10^{-10}$ $20·0 \times 10^{-10}$ $50·0 \times 10^{-10}$	—	11·57	27·8
	Hertzrücken, Butsyk and Golubenko[27]	— V	—	13·4	465 483 501 519 538	30×10^{-10} 81×10^{-10} 210×10^{-10} 240×10^{-10} 1480×10^{-10}	—	—	46·0
	Mehl, Rhines and von den Steinen[16]	I B. and II	99·98	20·18 and 40·02	400 449	See Fig. 3		—	25·8*

† 0·1 atomic % level.
* Obtained from an average slope between concentration limits.
‡ Value from Dushman and Langmuir's equation. (*Phys. Rev.*, 1922, **20**, 113)

impurity atoms in the core will slow down the diffusion rate of magnesium. Thus the greater the purity of materials used in the experiments the more reliable will be the resultant diffusion coefficient.

Although the results may not be of absolute significance, a useful indication of relative effects can be obtained. Results obtained from one specific worker will indicate an order of magnitude of the movement of solute elements, and relative rates of diffusion for the different elements. Table V shows this for a temperature in the region of 500° C. It may be concluded from this that in the neighbourhood of 500° C. the relative rates of movement of solute atoms in aluminium in ascending order is: manganese, copper, silver, silicon, magnesium and zinc.

The most informative method of presentation of experimental results is obtained when they are arranged to give two final graphs, one a graph of the diffusion constant, D_o, against concentration, the other a graph of activation energy against concentration. The information available in these two graphs is such that the diffusion coefficient can be rapidly calculated at any temperature and concentration within the concentration ranges covered by the experiments. This method has been used by Horne and Mehl[31] in their work on diffusion in α-brass, and by Bückle and Descamps[11] in their work on the diffusion of beryllium in aluminium. The results from the latter work are shown in Fig. 1, and will be used to illustrate the method. Curves were plotted showing the variation of the diffusion coefficient with concentration at four temperatures, using microhardness measurements (Fig. 1*a*); the extent of these curves is naturally governed by the solid solubility at the temperatures studied. From these curves, a graph of log D against $1/T$ was drawn for three fixed concentrations (Fig. 1*b*). The intercepts and the slopes of these graphs give the activation energies and diffusion constants shown in Table III. These have been drawn in the form of graphs in Fig. 1*c* and *d*. It will be observed from Fig. 1*c* that the curve can be extrapolated back to give an activation energy of 37–38 k.cal./g.-atom at a solute concentration of zero. This agrees well with the activation energy for self-diffusion estimated by Kê[7].

The difficulty in extracting the above information from the results of previous work is that at most only three temperatures are covered and a straight line through three points is seldom likely to lead to a high degree of accuracy; at least five points are necessary to give a reasonable result.

Radioactive isotopes have not yet been used to study the diffusion of solute elements in aluminium, and this would appear to be a serious omission. The method should not be impracticable, since aluminium isotopes are mostly short-lived. A diffused couple could be suitably irradiated and, after waiting for the aluminium

TABLE V.—DIFFUSION COEFFICIENTS AT 500° C.

	$D \times 10^{10}$ (sq. cm./sec.)					
	Mn	Cu	Ag	Si	Mg	Zn
Beerwald[13]	—	4	7	10	14	20
Bückle[14]	<1*	5	—	12	20	—
Mehl, Rhines and von den Steinen[16]	—	6	—	12	18	Difficult to assess

* A figure at 500° C. is not available for manganese, but the figure of 1×10^{-10} sq. cm./sec. for diffusion at 600° C. indicates it to be $<1 \times 10^{-10}$ sq. cm./sec. at 500° C.

TABLE IV.—SHOWING THE EFFECT OF ZINC AND SILICON ON THE DIFFUSION COEFFICIENT OF MAGNESIUM IN ALUMINIUM

	Author(s)	Experimental Methods Used (see Tables I and II)	Initial Concentration of Core (wt. %)	Temperature (° C.)	Diffusion Coefficient, D. (sq. cm./sec.)	
					Magnesium in Aluminium	Magnesium in Aluminium + 2·7 wt. % Zinc
Diffusion of Magnesium in the presence of Zinc	Bungardt and Bollenrath[17]	D. I	4·7–7·2	415 420 475 480 500 520 540	— $0·77 \times 10^{-10}$ $7·3 \times 10^{-10}$ $8·5 \times 10^{-10}$ $22·0 \times 10^{-10}$ $87·0 \times 10^{-10}$ —	$0·34 \times 10^{-10}$ — $3·7 \times 10^{-10}$ — — $22·0 \times 10^{-10}$ $65·0 \times 10^{-10}$
					Magnesium	Silicon
Diffusion of Magnesium and Silicon together	Freche[19]	B. II	1·21 Mg 1·95 Si 1·21 Mg, 0·63 Si } Al–Mg_2Si 1·61 Mg, 1·35 Si } Al–Mg_2Si +Si	450 510	$19·0 \times 10^{-10}$ — $38·0 \times 10^{-10}$ $11·0 \times 10^{-10}$	— $20·0 \times 10^{-10}$ $19·0 \times 10^{-10}$ $13·0 \times 10^{-10}$

isotopes to decay away, the solute concentration could be estimated by means of the still active solute atoms. The accuracy of analysis by this method is such that measurements to 1% of the solute concentration are possible. This compares with an accuracy of about 2% at a 3% concentration level and 10% at a 0·002% concentration level for chemical or spectrographic measurements. The reliability of the resultant diffusion coefficients should therefore be greatly improved wherever this method is applicable.

Acknowledgments

The author wishes to thank Aluminium Laboratories Ltd., for permission to publish this paper and his colleagues for helpful discussions.

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Removal of Sulphur from Coke Oven Gas

AFTER ten years of experiments and pilot plant trials, Appleby-Frodingham Steel Co., a branch of the United Steel Cos., Ltd., have developed an entirely new combined desulphurising and sulphuric acid plant, which is claimed to incorporate major advances on any existing similar process. The first full-scale plant is now being installed at Appleby-Frodingham and is due for completion by mid-1959.

At most integrated steelworks, a certain proportion of coke oven gas is used to fire the open hearth melting furnaces, the remainder being used in reheating furnaces and soaking pits. This gas contains about 1% of sulphur which, apart from adding to the difficulties of making low sulphur steel, results in considerable quantities of sulphur dioxide being released into the atmosphere. In an integrated works making one million tons of steel ingots a year, the use of the Frodingham desulphurising process enables the sulphur dioxide to be recovered, from which as much as 250 tons of sulphuric acid can be produced each week.

In the case of ordinary gasworks supplying town's gas, there is a statutory obligation to reduce the sulphur content of the gas to the equivalent of less than 2 parts per million by volume of sulphuretted hydrogen, a necessity which entails the provision of costly and extensive purification plant. Even after this is done, however, there remains a residue of organic sulphur which cannot be removed in existing purification equipment, and which causes corrosion in domestic hot water appliances.

The plant developed by Appleby-Frodingham, which consists essentially of a fluidised hot iron oxide absorber and regenerator, is capable of removing both hydrogen sulphide and organic sulphur to very low levels; at the same time, too, it enables the recovery of considerable quantities of sulphuric acid. The heat requirements of the plant are met by the combustion of the absorbed sulphur and, once started up, it is self-sustaining as far as heat is concerned.

A pilot plant has been in successful operation for two years, purifying up to 3 million cu. ft. of coke oven gas per day. The full scale plant, when completed, will deal with 32 million cu. ft. of gas per day.

Because the process employs hot gas, it is very much faster than conventional iron oxide boxes or purification towers, while the use of fluidised beds reduces the amount of spent oxide by four-fifths, and simplifies its handling and distribution. In compactness and capital cost, the process compares very favourably with existing methods, while the entire operation of the full-scale plant is capable of being handled by two men per shift.

Under the provisions of the Clean Air Act, the height of chimneys discharging sulphur dioxide to atmosphere may be subject to regulation and this, combined with the economic and technical factors already mentioned, suggests that the new Frodingham desulphurisation process is likely to be of particular interest to the steel industry, the gas industry—especially in the case of the larger gasworks—and the chemical and petroleum industries.

Appleby-Frodingham have appointed two licensees to build plants based on this process. They are Henry Balfour and Co., Ltd., of Leven, Fife, and W. J. Fraser and Co., Ltd., of Romford, Essex. The unit at present under construction at the Appleby-Frodingham works is being built by the latter company.

New Steel Film

THE story of steel in the service of agriculture from medieval times to the present day is told in animated cartoon form in the new sound colour film "Earth is a Battlefield," made for the British Iron and Steel Federation by the Larkins Studio in association with the Film Producers Guild, Ltd. It employs the little flat figures simplified almost into abstractions of human beings which are characteristic of modern entertainment cartoons. The dialogue is written in verse-parody throughout and ranges from Chaucerian English to contemporary Cockney. The background music has been specially composed. The film, which is available in 16 mm. and 35 mm. sizes runs for 11 minutes and can be obtained on free loan by writing to the Public Relations Department, British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1.

The Fatigue Strength of Specimens Cut from Pre-loaded Blanks

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Tests on specimens cut from the body, i.e. away from the surface, of material pre-loaded in various ways show that prior fatigue testing has no effect on the fatigue strength of aluminium alloy L.65. Static pre-loading in compression or torsion increases the fatigue strength of mild steel and decreases it for the L.65 aluminium alloy.

A SPECIMEN may be pre-loaded prior to subsequent fatigue testing, either by the application of a static load or by subjecting it to an alternating load. In either case subsequent tests can be divided into two categories :—

(*a*) those in which the pre-loaded specimen itself is re-tested, and

(*b*) those in which specimens for re-testing are cut from the body of the pre-loaded specimen or blank.

As the initiation of fatigue failure is essentially a surface phenomenon, the former tests must necessarily be of the greater importance in the study of the fundamentals of the fatigue process. For this reason the subject of cumulative damage has been studied extensively by means of fatigue tests in which the load on the specimen is varied throughout the life in either a regular or random manner. If the specimen contains a notch, then pre-loading may result in residual stresses being induced at the notch root. High tensile static pre-loading of such specimens will induce favourable residual compressive stresses on unloading, which will lead to enhanced fatigue strengths on subsequent testing. A comprehensive bibliography of such work, including both static and fatigue pre-loading, is given by Roylance.[1] The purpose of the present paper is to investigate any change in fatigue properties of the material remote from the surface, and hence is confined to tests of category (*b*) on plain specimens. While it is realised that such tests are of lesser importance than those previously mentioned, they are of a certain interest and practical significance.

During a fatigue test on a notched cylindrical specimen, it is possible for a crack to be growing slowly into the body of the specimen. It is of interest to know whether the material at a given point in the body of the specimen remote from the crack tip suffers permanent damage before the crack tip approaches the point. The effect of static pre-straining on subsequent fatigue strength is of interest in the machining of notches, holes, etc., in fatigue specimens. During the initial machining operations, the material around the notch may be severely work-hardened and, although a light finishing cut is taken, the whole volume of worked material may not be completely removed.

TABLE I.—COMPOSITION AND MECHANICAL PROPERTIES OF MATERIALS USED FOR TESTS.

Material	Test Mark	Chemical Analysis	Heat Treatment	Tensile Strength (tons/sq. in.)	0·1% Proof Stress (tons/sq. in.)	Elongation (% on 2 in.)
Mild Steel	TON	0·15% C 0·45% Mn 0·014% S 0·015% P	Normalised 920° C.	29	22 (Yield stress)	30
Aluminium Alloy B.S. L65	MBCG MBHQ	4·4% Cu 0·7% Mg 0·7% Si 0·6% Mn	Water quenched 505° C. and aged 160–190° C.	32	28	8

Smith[2] has shown that, for mild steel, the fatigue strength of small specimens cut from the body of previously fatigued larger specimens is not greatly affected by the prior fatigue loading : if anything, the fatigue strength is slightly higher than for the virgin material. Romualdi and D'Appolonia[3] and Kaufman and D'Appolonia[4] carried out fatigue tests on specimens machined from titanium alloy blanks statically pre-strained in torsion or tension. Specimens pre-strained 2% and 10%, respectively, in tension showed an increase in fatigue strength at 10^7 cycles. For specimens pre-strained in torsion to 10% of the total strain at fracture, an increase of 30% in the endurance limit was obtained, but only smaller additional increases were found for pre-strains up to 60%.

The present paper considers the effect of static com-

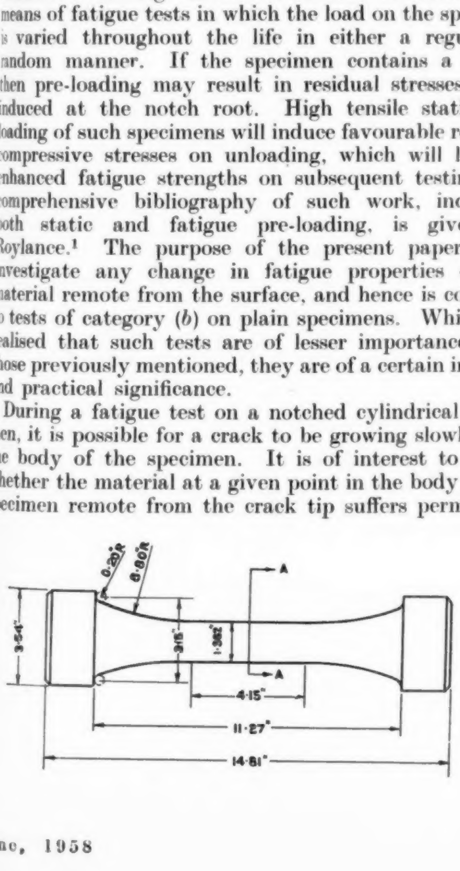
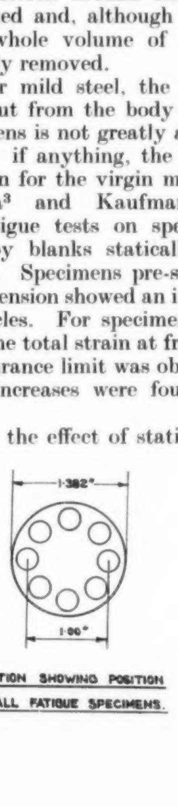


Fig. 1.—Details of large specimen for pre-loading by direct stress fatigue.



TEST SECTION SHOWING POSITION OF SMALL FATIGUE SPECIMENS.

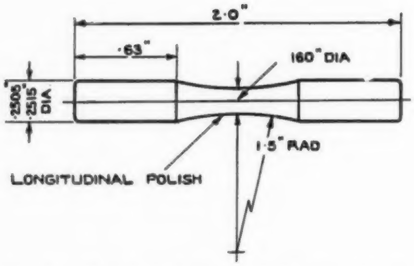


Fig. 2.—Small rotating bending fatigue specimen.

pressive and torsional pre-strain on both mild steel and an aluminium alloy, and also the effect of fatigue pre-loading on the latter material.

Experimental Details and Results

All initial blanks and specimens were cut with their longitudinal axes coinciding with the longitudinal axis of the bar material. Details of the chemical composition, heat-treatment and mechanical properties of the mild steel and aluminium alloy (B.S. L65) used are set out in Table I.

Effect of Pre-loading in Fatigue

The pre-loading tests were made in reversed direct stress, using specimens of 1·4 in. test diameter, as shown in Fig. 1. These were tested in a 60 ton capacity Schenck fatigue machine running at about 2,000 c./min. Four different pre-loading conditions were investigated, details of which are given in Table II.

TABLE II.—DETAILS OF FATIGUE PRE-LOADING CONDITIONS.

Specimen Mark	Applied Stress (tons/sq. in.)	Endurance (millions of cycles)	Remarks
MBCG 14N	± 4	0·151	Unbroken
MBCG 12G	± 10	26·106	Broken
MBCG 12D	± 12	1·759	Broken
MBCG 12C	± 11	11·672	Unbroken
	± 18	0·014	Broken

Small fatigue specimens of the type shown in Fig. 2, having a test diameter of 0·16 in., were cut longitudinally from the central section of the pre-loaded specimens, as indicated in Fig. 1. They were tested in a cantilever-type rotating bending fatigue machine running at 4,000 rev./min., and the fatigue strength of the virgin material was obtained using small specimens cut from an unloaded blank. The results obtained are shown

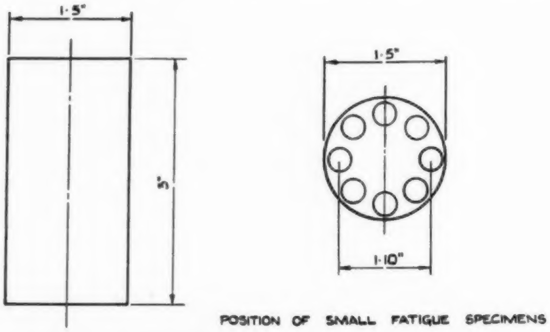


Fig. 4.—Blank for pre-loading in compression.

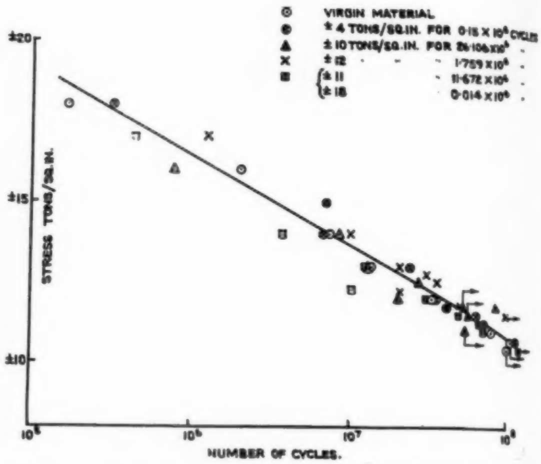


Fig. 3.—Effect of pre-loading by direct stress fatigue. Aluminium alloy.

plotted on Fig. 3. As would be expected, the small specimens give a somewhat higher fatigue strength for the virgin material than that indicated by the initial tests on the large direct stress specimens.

Effect of Static Pre-loading in Compression

Tests were carried out on both the mild steel and the aluminium alloy. The initial blanks, of dimensions given in Fig. 4, were compressed in a 200 ton hydraulic testing machine, appropriate gauge marks being made on them so that the permanent strain could be measured. The applied nominal stresses and corresponding permanent plastic strains used are given in Table III.

TABLE III.—DETAILS OF COMPRESSION PRE-LOADING CONDITIONS.

Material	Blank No.	Blank Diameter (in.)	Plastic Strain (% on 2 in.)	Nominal Stress (tons/sq. in.)
Aluminium Alloy	MBHQ 16C	1·5	11	41
	MBCG 7M1	1·5	15	42
	MBHQ 16H	1·5	19	43
	MBCG 14N	1·7	22	59
Mild Steel	TON 1M	1·5	7	28
	TON 3M	1·5	33½	56½

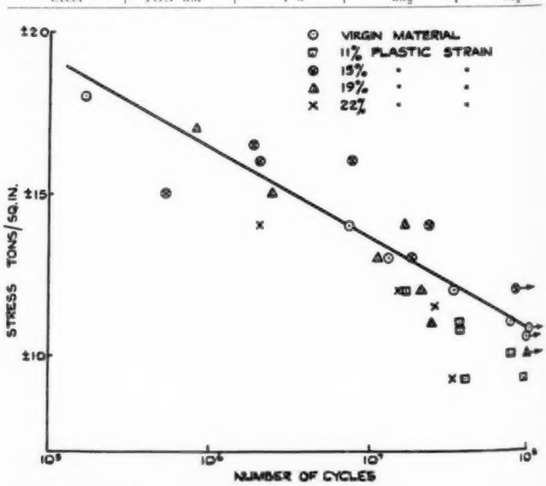
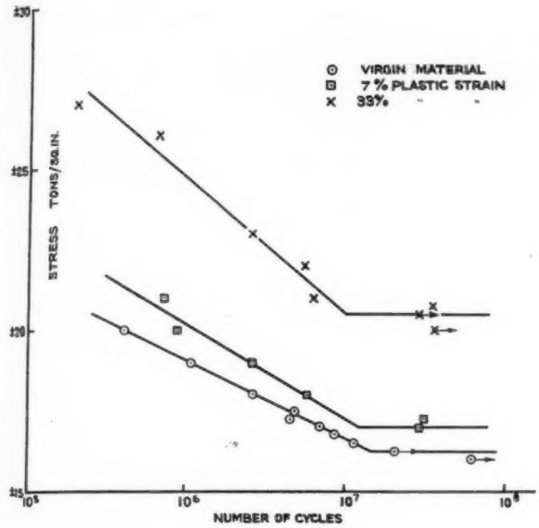


Fig. 5.—Effect of static pre-loading in compression. Aluminium alloy.



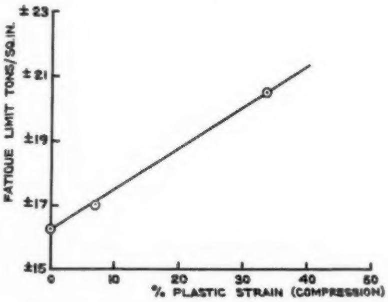


Fig. 6.—Effect of static pre-loading in compression. Mild steel.

Small fatigue specimens (Fig. 2) were cut longitudinally from the central section of the strained blanks, as indicated in Fig. 4, the testing conditions being as in the previous section. The results of the fatigue tests on the specimens cut from these blanks are shown plotted in Figs. 5 and 6.

Effect of Static Pre-loading in Torsion

The initial blanks for pre-straining were of the form shown in Fig. 7, and were twisted in a standard 60,000 in.-lb. capacity torsion machine. The applied torques and corresponding twists employed are given in Table IV. The plastic twist refers to the permanent twist of one end of the specimen relative to the other.

Small fatigue specimens (Fig. 2) were cut longitudinally from the central section of these blanks, as indicated on Fig. 7. They were tested as described in the

TABLE IV.—DETAILS OF TORSION PRE-LOADING CONDITIONS.

Material	Blank No.	Plastic Twist (degrees)	Applied Torque (in.-lb.)
Aluminium Alloy	MBHQ 2H	90	42,250
	MBHQ 2F	180	44,200
	(Fracture occurs at a torque of 44,400 in.-lb. with an angle of twist of 275°)		
Mild Steel	TON 8L	90	43,300
	TON 8G	180	47,700
	(Fracture occurs at a torque of 55,100 in.-lb. with an angle of twist of 630°)		

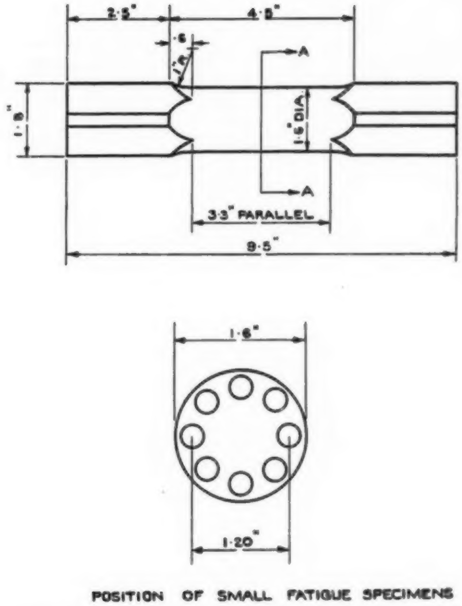


Fig. 7.—Blank for pre-loading in torsion.

previous sections, the results being shown plotted on Figs. 8 and 9.

Discussion

It can be seen from Fig. 3 that for the aluminium alloy there is little effect due to the various prior fatigue loadings, although there may be an indication that the highest pre-stressing causes a slight decrease in life for specimens breaking before 10^7 cycles. It is interesting to note the narrowness of the scatter band, especially in the region 10^7 to 10^8 cycles. It therefore appears that for the aluminium alloy prior fatigue loading causes no appreciable change of fatigue properties for the material in the body of the specimen, i.e. at positions remote from a free surface.

With the static pre-load tests there is considerable

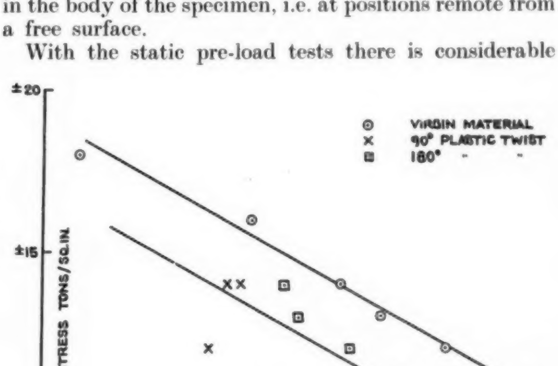


Fig. 8.—Effect of static pre-loading in torsion. Aluminium alloy.

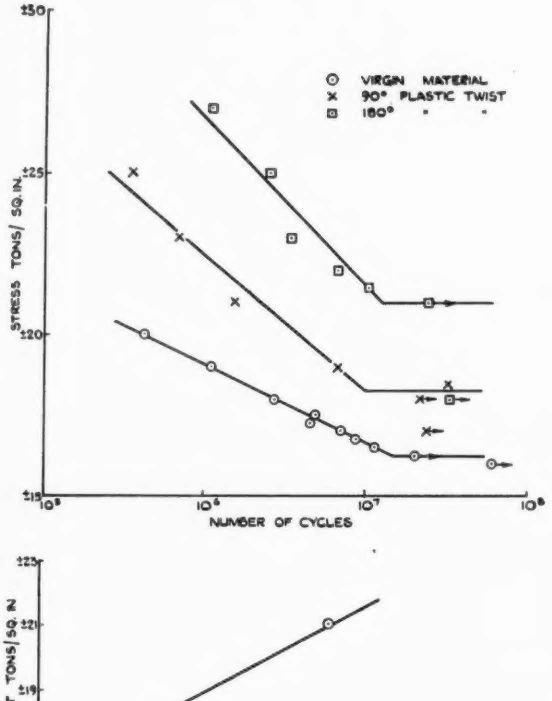


Fig. 9.—Effect of static pre-loading in torsion. Mild steel.

difference in behaviour between the mild steel and the aluminium alloy. For mild steel both the compression and torsion pre-loadings cause a definite increase in fatigue strength. Figs. 6 and 9 show that, over the range considered, the fatigue strength increases linearly with the amount of pre-strain. For the aluminium alloy there is no such increase in strength ; on the contrary, torsion pre-strain causes a definite decrease in fatigue strength (Fig. 8), and compressive pre-strain, while giving rise to some considerable scatter in results, again indicates that there is a tendency for the fatigue strength to be reduced (Fig. 5).

The results of the static pre-straining tests are important in the interpretation of notched fatigue results. In such tests, if it is desired to compare the notched fatigue results with theoretical predictions based on the intrinsic fatigue strength of the material, then it is apparent that any work-hardening of the material around the notch root during machining may invalidate any such comparisons. For mild steel it would be necessary to stress-relieve completely the finally machined notched specimens, but this does not appear possible with aluminium alloys of the type used (solution treated and artificially aged) as reheat-treating the finished machined specimen may set up compressive residual stresses at the notch root (Teed[5]). The results obtained also indicate why surface working such as shot-peening or rolling is more beneficial in the case of mild steel than aluminium alloy.

Conclusions

(1) The fatigue strength of specimens cut from the body (i.e. remote from the free surface) of large aluminium alloy specimens which have been subject to fatigue loading is not significantly different from that of the virgin material.

(2) Static pre-loading in compression or torsion causes an increase in fatigue strength for mild steel, the fatigue strength increasing linearly with the amount of pre-strain. Similar pre-loadings cause a decrease in the fatigue strength for the aluminium alloy.

Acknowledgments

The work has been carried out as part of the research programme of the Mechanical Engineering Research Board of the Department of Scientific and Industrial Research. The article is published by permission of the Director of Mechanical Engineering Research.

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Efco-Udylite Changes

Electro-Chemical Engineering Co., Ltd., announce that the present arrangements by which R. Cruickshank, Ltd., distribute and service Efco-Udylite processes non-exclusively will be discontinued from July 1st, 1958. From that date, supplies of addition agents and consumable products and full technical service will be available to all users of Efco-Udylite bright nickel and other processes in England, Wales and Northern Ireland from Electro-Chemical Engineering Co., Ltd., Sheerwater, Woking, Surrey (Tel. : Woking 5222). The Company has depots at Birmingham (Efco Depot, Booth Street, Handsworth, Birmingham, 21 (Tel. : Northern 5466)), and at Manchester (Chaddock Industrial Estate, Astley, Near Manchester (Tel. : Atherton 1364)). Stocks of all Efco-Udylite products are held at these depots for distribution to customers in the Midlands and North of England, and immediate delivery can be made.

The Hockley Chemical Co., Ltd., Hockley Hill, Birmingham, 18 (Tel. : Northern 6201) will act as selling agents in England and Wales of Efco-Udylite processes, and will provide full technical service to users. They will hold stocks of all materials for Efco-Udylite processes, and have regular delivery services throughout the country. In Scotland, Messrs. H. A. Dawson-Bowman, Brisbane House, Rowan Road, Glasgow, S.1, will distribute Efco-Udylite products on behalf of Electro-Chemical Engineering Co., Ltd. Resident technical service will be provided to all users of Efco-Udylite processes in Scotland.

New British Oxygen Factory

A new factory now being built in Glasgow will enable British Oxygen Gases, Ltd., to meet increased demands for their industrial gases in Scotland. The new 25-acre site is in close proximity to the company's existing factory at Polmadie, and a compressing station and stores together with a liquid oxygen plant will be erected there.

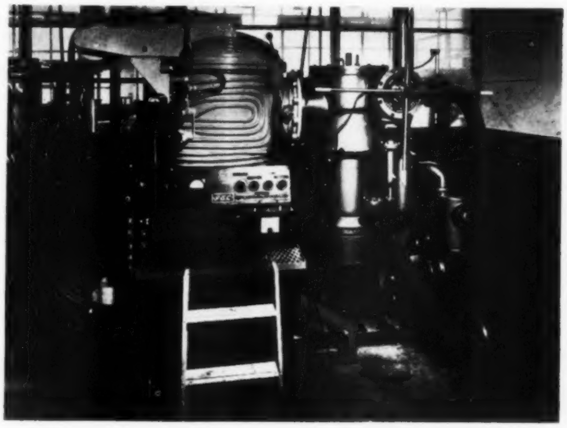
Recent Heat Treatment Furnace Installations

Annual Survey of Developments

The trend in design for certain specialised products has been on furnaces of increased capacity, while maintaining simplification of operation. Although orthodox designs predominate, improvements in details have, in many cases, increased efficiency. Greater attention has also been given to the constitution of the atmosphere surrounding work undergoing treatment. This review of recent installations indicates how designers and constructors are meeting industrial needs.

THE term " heat treament " has become associated with the hardening and strengthening of metals and alloys, whether ferrous or non-ferrous; strictly speaking, however, heat treatment has a much wider significance, and is applied to quite a number of processes which do not involve hardening or strengthening. Annealing, for instance, has for its object the softening of metals and alloys, frequently with a view to facilitating further fabrication, a process which is the reverse of that often associated with heat treatment. In addition to equipment for hardening, therefore, it is felt that, in a review of this kind, a wider field of applications should be covered; with this in view, reference will be made to additional processes for which furnaces are applied, and to induction heating equipment.

Although vacuum melting equipment, in which outstanding progress has been made during the last few years, is outside the scope of this review, vacuum heating is also being successfully applied for such operations as heat treating, brazing, sintering, etc. The G.E.C., for instance, have introduced a range of standard vacuum furnaces for such heat treatments as the brazing of heat-resisting alloys; sintering hard metals, heat-resisting alloys, and cermets; silver-soldering; outgassing; and annealing. These are vertical furnaces having a water-cooled cylindrical steel tank with hinged lid. A vacuum seal is made between flanges on the lid and the furnace body. The furnaces are internally heated and the charge is placed on a work stand in the centre of the heating-element assembly. Thermal insulation consists of radiation screens of selected material carefully positioned between the element and the tank to ensure efficient evacuation of the chamber. Installations are supplied complete with vacuum pumping equipment, the type depending upon the size of the furnace, the degree of vacuum required and the heating process. Vacuums up to 5×10^{-5} mm. mercury can be obtained. When fitted with molybdenum radiation screens and graphite heating elements, the furnaces provide temperatures up to 1,800° C. With alternative element and screen materials, temperatures up to 2,200° C. can be obtained, while small furnaces can be made for operation up to 2,600° C. Fig. 1 shows one of these vacuum furnaces installed in the B.S.A. Group Research Powder Metallurgy Laboratory. It provides temperatures up to 1,800° C. and an operating vacuum better than 10^{-4} mm. mercury. The evacuation of the furnace chamber is controlled by a valve block with a five-position operating lever, which can be moved only in one direction, to ensure the right sequence of operations. When the lever is in the final position all valves are closed, so that the furnace is isolated from the pump system and leak rate tests can be made.

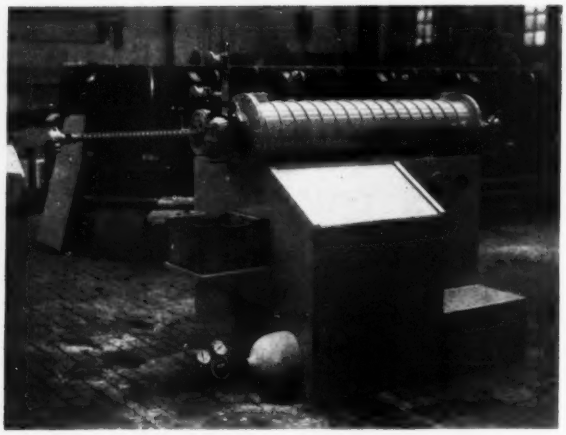


Courtesy of The General Electric Co. Ltd,

Fig. 1.—A high temperature vacuum furnace installed in the B.S.A. Group Research Powder Metallurgy Laboratory.

Many believe that some heat treatment projects should be thoroughly evaluated on a small scale. For this purpose, the Vacuum Metallurgical Developments, Ltd., laboratory furnace provides a basic vacuum pumping system in which nearly all metallurgical operations can be carried out under vacuum. This furnace has a 15-in. horizontal chamber with a front mounted door, and is pumped by a 4-in. high speed booster/diffusion system, backed by a suitable mechanical pump. The furnace chamber, which has a large diameter water-cooled heating element mounted on the door, may be used horizontally or vertically for heat treating, melting, vacuum brazing, sintering, and other operations involving temperatures up to 1,700° C.

A two-zone high temperature heat treatment furnace, shown in Fig. 2, was recently supplied to a Corporation in the U.S.A. It is typical of a range in which parts to be processed are inserted at one end into the first hot zone and subsequently transferred to the second zone by means of pusher rods. The parts can then be quenched within a few seconds by withdrawal on to a trap which falls open, allowing the parts to drop into a quenching tank.



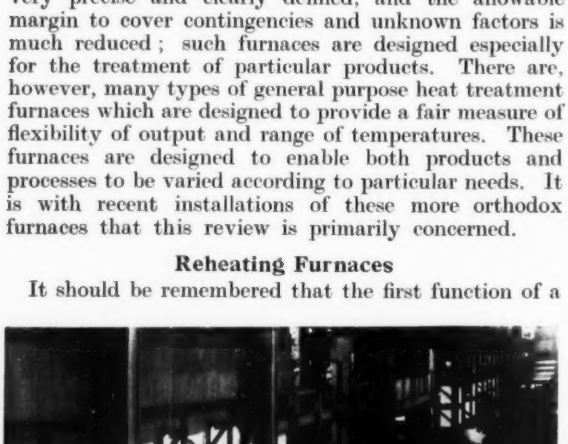
Courtesy of Vacuum Metallurgical Developments Ltd.

Fig. 2.—A two-zone vacuum heat treatment furnace. A general view showing front and discharge end.

While vacuum furnaces, whether for melting or the wider applications of heat treatment, have great value in the removal of gas from the charge, and in the prevention of oxidation during treatment, particularly in dealing with some of the newer metals and alloys, the bulk of heat treated products are processed in furnaces of more orthodox design. For mass production, the duty demanded of a heat treatment furnace is generally very precise and clearly defined, and the allowable margin to cover contingencies and unknown factors is much reduced; such furnaces are designed especially for the treatment of particular products. There are, however, many types of general purpose heat treatment furnaces which are designed to provide a fair measure of flexibility of output and range of temperatures. These furnaces are designed to enable both products and processes to be varied according to particular needs. It is with recent installations of these more orthodox furnaces that this review is primarily concerned.

Reheating Furnaces

It should be remembered that the first function of a heat treatment furnace, whether the heating medium be solid fuel, gas, oil, or electricity, is to give a satisfactory product at low cost, consistent with uniformity of heating. This applies to all types of furnaces and to varying processes. In steelworks, for instance, particularly in this country, the soaking of ingots has usually been carried out in furnaces heated by coke oven or blast furnace gas, or by a mixture of the two. In those works where these gases have not been available, producer gas or oil fuel has been used. While these heating media will continue to meet the bulk of ingot heating requirements, it is noteworthy that electric energy for ingot heating has been introduced in several works. In the Scandinavian countries, the use of electric energy for heating ingots has always been looked upon as a natural development because of favourable power costs. In recent years, however, the cost of gas, coal and oil in this country has risen much more steeply than that of electricity, and it has become reasonably economic to use electrical energy, particularly in soaking pits for special alloy steels.



Courtesy of Stein & Atkinson, Ltd.

Fig. 3.—An electric soaking pit at Appleby-Frodingham Steel Co.

Courtesy of Dowson & Mason, Ltd.

Fig. 4.—A continuous pusher type billet heating furnace.

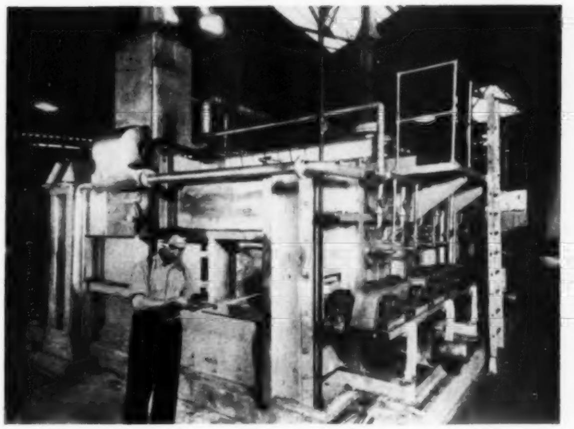
The electric pit consists essentially of a well-insulated steel-encased pit, divided into a series of separate compartments, each with its own cover. The heating element is one or more silicon-carbide troughs filled with low ash petroleum coke. Power is supplied to the troughs from transformers equipped with tap-changing equipment to give a variable secondary voltage. When current passes, the coke in the troughs becomes incandescent and forms what is in effect a radiant resistor. Temperatures are measured and controlled by conventional means, and a fully automatic control system enables a high degree of precision and uniformity of temperature to be attained. Special care is taken to ensure that the pit and covers are air-tight, to prevent ingress of atmospheric air, thus facilitating control of the pit atmosphere.

Three installations of this type provide examples of the versatility of this form of heating. At Colvilles, Ltd., Motherwell, an electric pit with a power input of 1,000 kVA. is used for heating composite and special steel slabs for rolling to plates. The essential requirement in this instance is uniformity of heating and no scale formation. At Samuel Fox, Ltd., an electric pit with a power input of 1,100 kVA. is being used for heating for rolling a wide range of steel qualities in the form of ingots pre-heated in gas-fired furnaces to about 800° C. At the works of Appleby-Frodingham Steel Company an electric pit, with a power input of 950 kVA. and a holding capacity of 80 tons, is being used to heat short track time 10-ton slab ingots. In this case, advantage is taken of the high thermal efficiency of the electric pit at high charging temperatures to attain an economic energy consumption even without taking into account the extra yield due to scale saving : Fig. 3 shows this pit. Two further electric pits now under construction at the works of the Consett Iron Co., Ltd., will have a total holding capacity of 280 tons, and are also intended for short track time steel.

The continuous pusher type billet heating furnace shown in Fig. 4 has been installed at the works of Redheugh Iron and Steel Co., Ltd., Gateshead. It is fired by town's gas through three large burners mounted in the end wall of the discharge end and directed horizontally along the length of the furnace towards the charge end and above the billets on the hearth. The overall length from charge door to discharge point is 34 ft., and the width inside the walls is 6 ft. 6 in. The charge, in general, consists of mild steel slabs 3 in. thick, a maximum length of 5 ft. and width ranging from 12 to 20 in. The rated output is 4 tons/hr. and the working temperature, 1,280° C., but it has been found in practice that 100 tons is obtainable in 22 hours working time, comprising three consecutive 8-hour shifts with meal breaks. Billets are charged through an end door by a hydraulic pusher operating over a charge table, and discharge is through a side door by a manually-controlled power-operated discharge machine.. The burners are of the selective flame type. Automatic temperature control is by a Kent single point pneumatic recording controller and thermocouple, with proportioning type gas and air valves operated by power cylinder. Although orthodox in general layout, this furnace indicates what can be achieved in efficiency of operation by details in design.

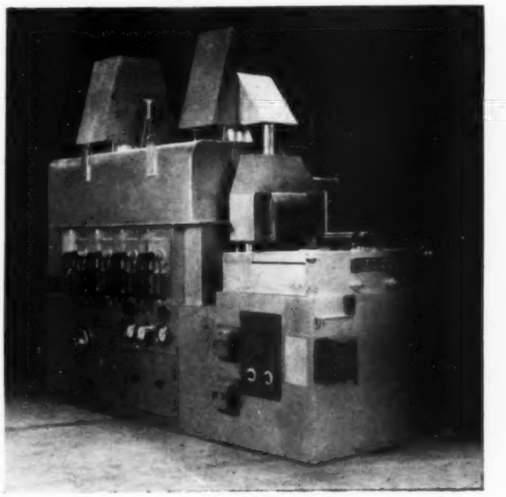
A gas-fired screw type conveyor furnace, which is designed for heating 200 bars per hour for coiling into automobile springs, is shown in Fig. 5. The four horizontal furnace conveyor screws are charged by an automatic device from a magazine, the bars being automatically discharged by a series of hot rollers which convey the heated bars to a discharge point in the side of the furnace, which is so arranged as to feed directly into the starting point of the mandrel of the coiling machine. The furnace is fired by Thermic low pressure type Eddy Ray gas burners firing both above and below the work ; they operate in conjunction with air at approximately 250° C., the air being preheated by metallic recuperators arranged on the two main waste gas exhaust stacks. The bars, which vary in diameter from $\frac{1}{2}$ to $\frac{7}{8}$ in., are heated uniformly throughout at temperatures up to 970° C. In addition to uniform heating, this furnace produces bars free from surface markings, and contamination is kept within commercial limits.

A furnace specially designed for heating alloy steel forging blanks in a specially prepared atmosphere, is shown in Fig. 6. This self-contained unit is complete with exothermic atmosphere generating plant mounted below the furnace, which has an output of approximately 150 lb./hr. of blanks at 1,180° C. The parts for treatment are pushed through the furnace in thin walled heat resisting steel tubes located in a heat resisting steel muffle which extends in the form of a sloping tube emerging at the rear of the furnace. The pusher gear comprises pneumatic twin pushers, operating in alternate sequence and electronically timed. In an emergency, the pushers can be operated by push buttons. The furnace is heated by a series of gas and air blast burners firing alternately from each side of the muffle of the furnace into refractory lined passages below the muffle, and exhausting through damper controlled flues at each end of the furnace. The burners are designed to consume town's gas delivered at a pressure of 2–3 in. w.g., in conjunction



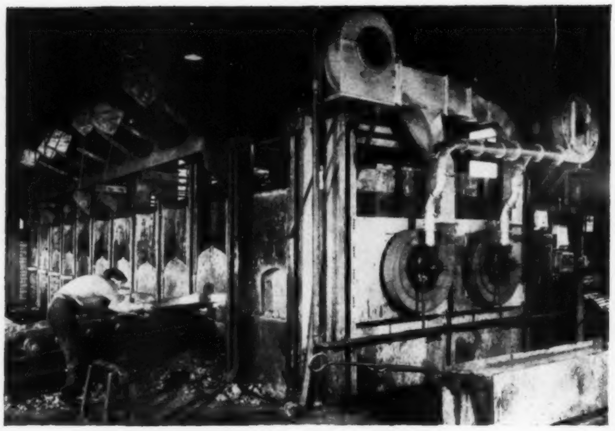
Courtesy of Thermic Equipment & Engineering Co., Ltd.

Fig. 5.—A gas-fired screw type conveyor furnace for heating bars to form coil springs.



Courtesy of Metalectric Furnaces Ltd.

Fig. 6.—Controlled atmosphere pusher type forging blank furnace.



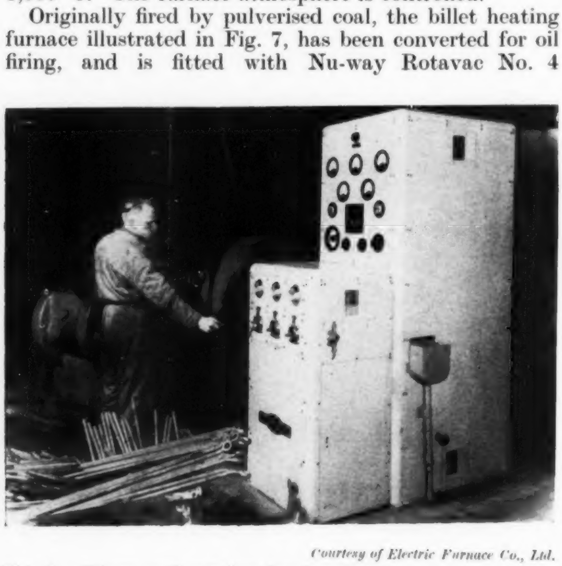
Courtesy of Nu-way Heating Plants, Ltd.

Fig. 7.—Billet heating furnace fitted with Rotavac Type W.S.F. oil burners.

with air supplied by the low pressure blowing fan included in the equipment.

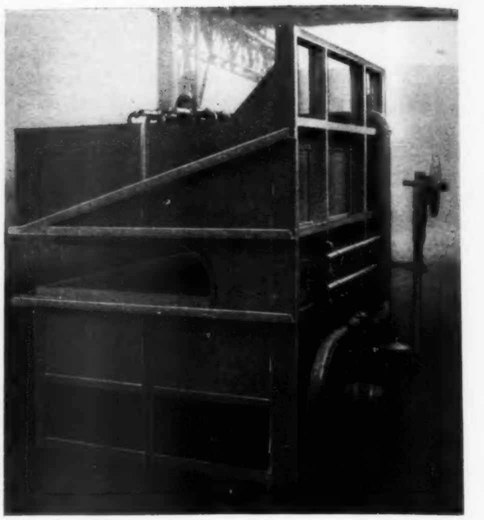
A G.E.C. rotary hearth furnace has been supplied to the Birmingham Battery and Metal Co., Ltd., for the heating of brass and copper billets prior to extrusion. The furnace is circular in section, and the hearth is carried on a circular cast base plate supported on three wheels running in roller bearings. Flanges on the furnace casing bed down into sand channels on the periphery of the hearth to reduce gas and heat losses as far as possible. The hearth is driven by a squirrel cage induction motor operating through reduction gears. Entrance and exit doors are arranged side by side and are raised pneumatically. The doors remain open only so long as the operating foot pedals are depressed, thus ensuring that they are not kept open longer than necessary. The furnace is rated at 240 kW., and provides for temperatures up to 1,000° C. The furnace atmosphere is controlled.

Originally fired by pulverised coal, the billet heating furnace illustrated in Fig. 7, has been converted for oil firing, and is fitted with Nu-way Rotavac No. 4



Courtesy of Electric Furnace Co., Ltd.

Fig. 9.—Three-coil station for heating bar ends prior to upsetting.



Courtesy of Dowson & Mason, Ltd.

Fig. 8.—A slot furnace for heating the ends of parts to be swaged.

WSF burners on forced secondary air directors, each burning approximately 54 gal./hr. of heavy fuel oil. This type of burner is used with low air pressure, and the high velocity atomisation gives a very high efficiency. The removable inner assembly simplifies maintenance and the nozzle is protected from radiant heat damage. Control systems applicable include manual, semi-automatic, modulating or fully automatic high-low/on-off with gas-electric ignition. The flame shape regulator permits adjustment of the flame to the shape required while the burner is in operation, and the soft gaseous flame ensures long refractory life. This furnace is reputed to be the most efficient of its type ever tested by N.I.F.E.S., and the change in fuel has given much better atmosphere control, improved output, and significant scale reduction.

There are many instances where heating of the ends of stock is required and it is unnecessary or undesirable to heat more than is actually needed. Typical examples include heating tube ends for swaging prior to cold drawing; heating the ends of automobile axles for upsetting; heating partly-formed bends in superheater tubes prior to full closure; and heating the ends of leaf spring plates for eye rolling. The slot furnace shown in Fig. 8 is a typical example of the type of furnace suitable for this work. This furnace is gas fired by fan blast type burners, and is specially designed for location alongside a conveyor carrying the stock, the projecting ends of which pass through the heating chamber. In this way it forms a small and compact continuous unit, but it may also be used for manual operation for such purposes as pipe and bar bending.

Induction heating is also frequently used for preparing the ends of bars for hot working, and Fig. 9 shows a simple three-coil station for heating the ends of bars prior to upsetting. The coils are 7 in. long, and are connected in parallel to a 50 kW. 10 kc./s. generator. The coils are loaded in sequence, and at the end of the pre-determined heating time the bars are partially ejected in turn, removed and replaced.

Stress-Relieving

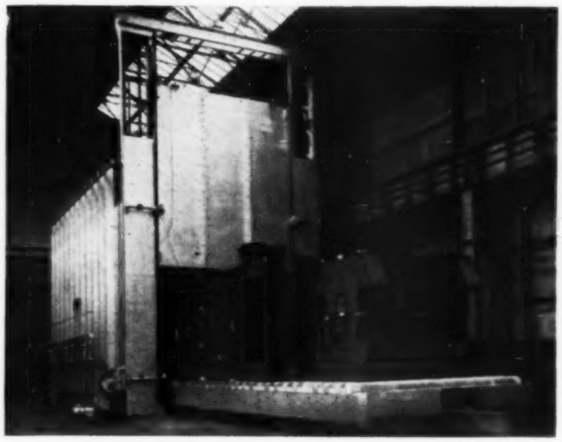
Stress-relieving is an important heat treatment applied for the purpose of removing residual stresses from components which must not be heated to temperatures above the critical range, and in which residual stresses detrimentally affect the component in service. The most common cause of these stresses is unequal heating or cooling, or both, such as occurs in welding or in the cooling of cast or forged parts of widely varying cross sections. Many furnaces are specially designed for this form of heat treatment, and that shown in Fig. 10 is a typical example. It is primarily used for heat treating large welded structures and its normal load is 100 tons. Heat is imparted around the sides, over the top, and under the components being treated. Town's gas is the heating medium, and for heating and soaking a 100-ton charge, the gas consumption is below 5,000 cu. ft./ton of fabrications treated.

This furnace, which is installed at the Elswick Works of Vickers-Armstrongs, Ltd., is of the bogie type, incorporating the Mathison vertical flame application to eliminate any flame impingement on the components being treated; it also incorporates high speed recirculation of the hot products of combustion, by means of an external, electrically operated recirculating fan. Automatic pyrometric control gear, in six banks, is incorporated to maintain the temperature throughout the full length of the furnace within a fine degree of accuracy. More recent installations, embodying similar principles, include a larger furnace capable of stress-relieving vessels up to 20 ft. in diameter for nuclear power work.

An electrically heated bogie hearth furnace, used for stress-relieving welded cast gear box covers and forged coupling rings, is shown in Fig. 11. Heat resisting steel plates cover the top of the insulated bogie, which can carry up to 3 tons in weight. Strip heating elements are fitted in the hearth under the cover plates, and special mating contacts at the back end of the bogie butt up against corresponding contacts fitted at the rear of the heating chamber. As the furnace operates only up to 650° C., an air circulating fan is fitted in the furnace roof to give forced convection and assist in achieving a high degree of thermal uniformity within the working chamber.

Courtesy of G.W.B. Furnaces, Ltd.

Fig. 11.—An electrically heated bogie hearth furnace for stress-relieving welded cast gear box covers and forged coupling rings.



Courtesy of John Mathison, Ltd.

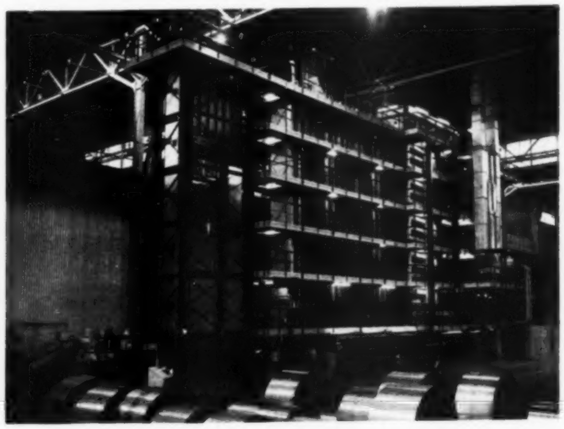
Fig. 10.—A stress-relieving furnace for heat treating welded structures installed at the Elswick Works of Vickers-Armstrongs, Ltd.

Heating elements are also located under the arched roof of the furnace.

Annealing and Normalising

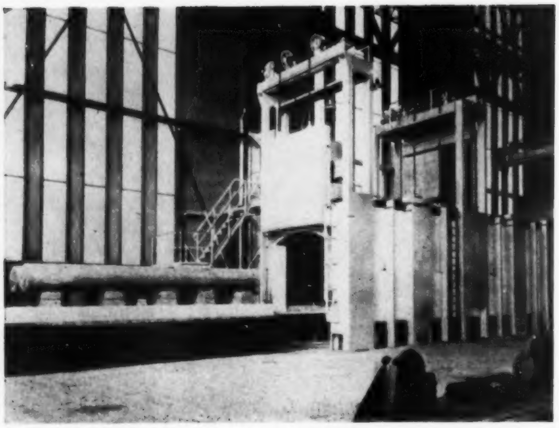
The annealing operation consists of heating the material to some predetermined temperature, maintaining this temperature constant for a given length of time, and cooling it at a predetermined rate to atmospheric temperature. There may be one or more of several objectives involved in annealing, but its main purpose is to soften the material to facilitate further operations. Many types of furnace have been designed for this form of heat treatment, probably the largest of these recently installed being the continuous vertical tinplate annealing and cleaning line at the Velindre Works of the Steel Company of Wales, Ltd.

This plant, the entry end of which is shown in Fig. 12, cleans and anneals tinplate strip up to 38 in. wide at a speed of 600 ft./min.: that is one coil of 30,000 lb. every hour. It is 210 ft. long and 53 ft. high and was manufac-



Courtesy of The Incandescent Heat Co., Ltd.

Fig. 12.—A continuous vertical tinplate annealing furnace installed at the Velindre Works of the Steel Company of Wales, Ltd.



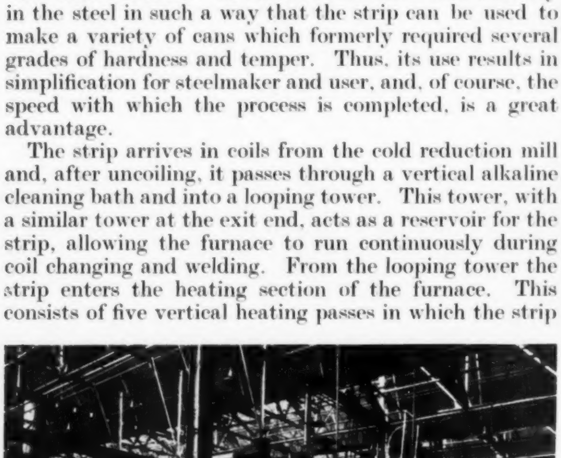
Courtesy of Metalectric Furnaces, Ltd.

Fig. 13.—A bogie hearth furnace designed for the heat treatment of ships' propeller shafts.

tured and installed by Incandescent Heat Co., Ltd., as main contractors, in collaboration with their associates, the Drever Company of Pennsylvania, U.S.A. The strip handling equipment was supplied by Davy and United Engineering Co., Ltd.

Continuous annealing of tinplate has several advantages over older methods. It combines hardness and ductility in the steel in such a way that the strip can be used to make a variety of cans which formerly required several grades of hardness and temper. Thus, its use results in simplification for steelmaker and user, and, of course, the speed with which the process is completed, is a great advantage.

The strip arrives in coils from the cold reduction mill and, after uncoiling, it passes through a vertical alkaline cleaning bath and into a looping tower. This tower, with a similar tower at the exit end, acts as a reservoir for the strip, allowing the furnace to run continuously during coil changing and welding. From the looping tower the strip enters the heating section of the furnace. This consists of five vertical heating passes in which the strip



Courtesy of G.W.B. Furnaces, Ltd.

Fig. 14.—A multi-purpose electrically heated driven roller hearth furnace for normalising, cyclic annealing and stress-relieving various components.

is heated to the annealing temperature (730° C.) in 17·4 seconds. The high heating rate is obtained by using ninety-two Jetube radiant heating elements. The soaking zone consists of two electrically heated passes, after which the strip enters three cooling zones. The first is a slow cool to reduce the temperature to 425° C.; then follows a fast cool to 120° C.; and finally a forced air cooling section reduces the temperature to 65° C. The exit end looping tower and coiling gear complete the line. A protective atmosphere is used to prevent oxidation of the strip during treatment

The bogie hearth furnace, shown in Fig. 13, has recently been installed in a shipbuilding works in Holland; it is designed specially for the heat treatment of ships' propeller shafts up to 45 ft. long, with a charge weight of 100 tons. The furnace is divided in the length, as is the bogie, so that smaller charges may be more economically treated when the total length is not required. The outer and inner doors are motor operated, and the bogie is mechanically driven in such a manner that the two hearths may be used together or separately. The furnace is electrically heated, the total rating being 2,300 kW., divided into fifteen separately controlled heating zones. It is designed to operate up to a maximum temperature of 1,000° C.

Unusual multi-purpose requirements have resulted in a specially designed electrically heated driven roller hearth furnace for carrying out normalising, cyclic

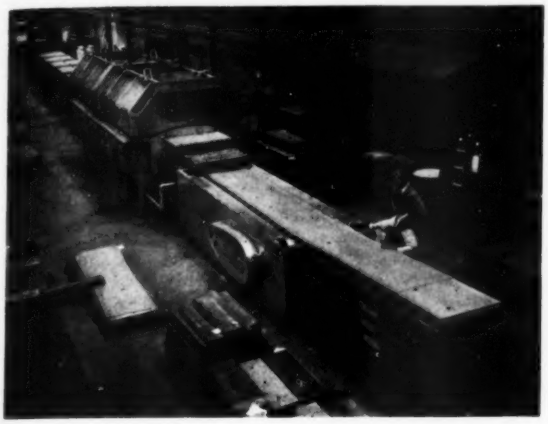
Courtesy of Dowson & Mason, Ltd.

Fig. 15.—A portable cover type furnace installed at the Crewe Works of Midland Rollmakers, Ltd.

annealing and stress relieving of a variety of components. This installation, shown in Fig. 14, is virtually in two sections: a high temperature (950° C.) furnace followed by a forced draft cooling section, and a 650° C. heating chamber followed by a slow cooling section. For normalising, welded structures are heated to 900° C., and cooled; for cyclic annealing, gear forgings are heated to 950° C., cooled to 550° C. and reheated to 650° C.; in the stress-relieving operation, partly machined forgings, such as crankshafts and gear blanks, are stress-relieved between 550 and 650° C., and cooled to 200° C. in the final 8 ft. 6 in. cooling chamber. Air circulating fans are fitted in each of the heating sections.

The heat treatment of mill rolls is exacting, and is becoming more critical with increased size and more

severe service duties. Furnace equipment must have larger working chambers than formerly, with greater control over temperature and closer uniformity. To meet these conditions a new furnace (Fig. 15) has been installed at the Crewe Works of Midland Rollmakers, Ltd. This is a portable cover type furnace, 25 ft. long, 10 ft. 3 in. wide and 6 ft. $4\frac{1}{2}$ in. high to the crown of the arch, with an effective hearth area of 22 ft. by 8 ft. 9 in. It is fired by town's gas from forty vertical luminous flame burners (twenty per side) with preheated air from underhearth recuperator tubes. The burners are grouped in two automatic control zones, each having a single-point indicating controller with programme regulator,



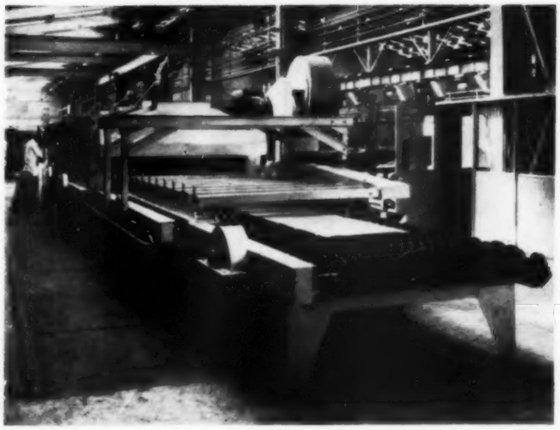
Courtesy of Metalectric Furnaces, Ltd.

Fig. 16.—A continuous annealing furnace for transformer sheets installed at the works of Joseph Sankey & Sons, Ltd.

connected to a modulating type valve positioner coupled by mechanical linkage to a pair of proportioning valves (one gas and one air) specially characterised to give enhanced sensitivity of control at low flows. One two-point strip chart temperature recorder provides a record of both control temperatures, the thermocouples being of the duplex type. Temperature uniformity is checked by a six-point strip chart recorder, a number of suitable entry holes, with sealing flaps, being provided in the hood so that the position of the six thermocouples can be selected at will, according to individual charges. The programme regulation is of the interchangeable cam type and permits the presetting of a time-temperature curve up to 72 hr. duration. Controlled heating rates of as low as 5° C./hr. are being obtained from 70° C. with temperature uniformity within ± 10° C. in the lower ranges and ± 5° C. in the higher ranges. Although primarily for temperatures up to 1,000° C., the furnace has been designed for 1,100° C. maximum for occasional special cycles. The design capacity is for a 60 ton charge.

A further furnace for the continuous heat treatment of transformer sheets has been installed at the works of Joseph Sankey & Sons, Ltd. With this installation (Fig. 16), small or large stampings are loaded directly on to a meshbelt conveyor ; since the furnace is continuous, the stampings can be of any length. The method gives completely uniform annealing and sheets are flat and free from distortion. The unit is rated at 150 kW. and has an output of 600 lb./hr.

A specially designed disc roller hearth furnace is

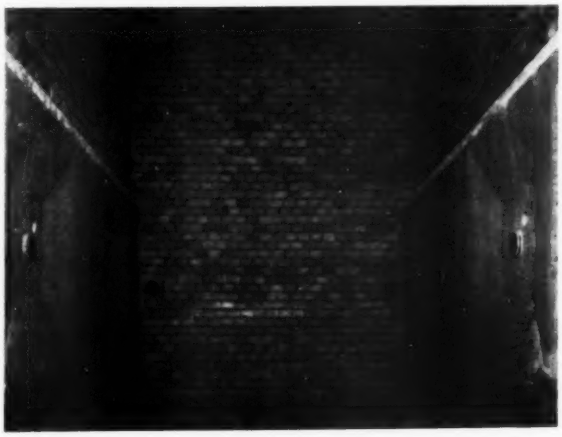


Courtesy of G.W.B. Furnaces, Ltd.

Fig. 17.—A specially designed disc roller hearth furnace for annealing thin sheets.

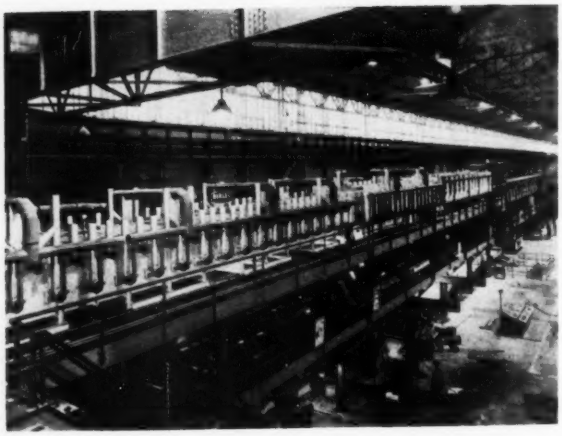
shown in Fig. 17. The driven rollers are of heat resisting steel and are located inside the furnace, which operates up to 1,100° C., and are of a similar disc form to the rollers at the unloading end. This type of roller is often preferred for sheets in the thinner gauges, where the front edge might tend to curl down between the normal type rollers of the plain cylindrical shape. In addition, a more evenly spaced support is given under the sheets or strips.

Over recent years the portable hood type annealing furnaces used for annealing steel sheet and tinplate have been developed in this country to give increased outputs. To this end direct firing of this type of furnace has been used, as opposed to the usual radiant tube firing. A well-known type of direct firing was introduced some years ago by the Salem Engineering Co., Ltd., under licence from Furnace Engineers, Inc., U.S.A. Further developments of this design by Salem in this country have greatly increased the maximum fuel inputs, on similar sized furnaces, over American practice. More recently, interest has centred round a new development,



Courtesy of Salem Engineering Co., Ltd.

Fig. 18.—Interior view of portable hood type furnace showing new R.W. burners in position.



Courtesy of Birlec, Ltd.

Fig. 19.—General view of the continuous galvanising line at Ebbw Vale

known as the R.W. burner, which is the subject of patent applications in this country and abroad. Applications of this new burner to existing hood type annealing furnaces have proved so successful that a new plant has been built in North Wales utilising eight of these burners per furnace to give a maximum heat input of the order of 15 million B.Th.U./hr. for a total load of 200 tons of coils. Fig. 18 shows the interior of one of these furnaces with the new R.W. burners in position.

The new type burner is of the nozzle mixing type, which gives a flat circular flame close to and in contact with the furnace walls. To make full use of the high B.Th.U. input for treating steel coils, it is necessary to instal fans under each pedestal supporting the coil stacks. These fans circulate a protective atmosphere around the coils within the steel covers; test figures show that a protective atmosphere circulation of approximately 13,000 cu. ft./min. can be obtained.

Another recent Salem development has been the installation of the first portable multi-stack cooling hood in South Wales, which has resulted in a reduction of 25 to 30% in the cooling time required before the coils can be stripped.

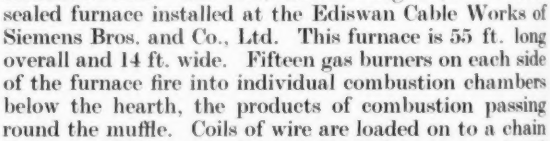
Outstanding among recent developments is the continuous galvanising plant installed at Ebbw Vale (Fig. 19). Designed and built by Birlec, Ltd., the furnace equipment of the new line incorporates the latest advances in production technique and quality control. Essentially, the equipment comprises a flame heater, a normalising, or annealing furnace, and an electrically heated galvanising bath. It is used for the annealing or normalising and subsequent galvanising of cold rolled mild steel strip in continuous form. Before annealing, the strip is oxidised and then reduced in a suitable controlled furnace atmosphere, a surface being obtained to which the zinc used for galvanising bonds securely. In this process a thin adherent coating can be obtained.

The overall length of the complete line is almost 680 ft. Nearly 500 ft. of this is taken up with the Birlec equipment, which has an overall width of 36 ft. and a height of 30 ft. The plant is designed to deal with strip up to 48 in. wide and to give an average output of 7 short tons/hr., based on strip 30 in. wide, in thicknesses ranging from 0·0095 in. to 0·05 in. The speed of the flow ranges from 30 to 250 ft./min.

The strip passes through the various units in sequence on a driven roller conveyor, beginning with the gas-fired flame heating section, where it is heated to approximately 450° C. to burn off the rolling oil and oxidise the surface. It is then passed through the heating section of the reducing furnace, where its temperature is raised to 845° C. This section of the furnace is heated by gas-fired radiant tubes. In the next section, which is electrically heated, the strip is held at a constant temperature, while the oxide on its surface is reduced and annealing takes place. It then enters the controlled cooling sections, whence it emerges at approximately 600–510° C. (depending upon the requirements of the zinc bath) over a turn-down roll leading into a tunnel to the galvanising bath. This bath is 13 ft. by 12 ft., with an overall depth of 7 ft. 6 in. It is provided with heavy electric heating elements for the initial melting of the zinc. Except during topping up, heat from the strip itself normally holds the bath temperature at about 450° C. From the time the strip enters the reducing furnace, until it emerges from the tunnel into the zinc bath, it is surrounded by a protective atmosphere formed from dissociated ammonia, supplied to all chambers from Birlec ammonia cracking plant.

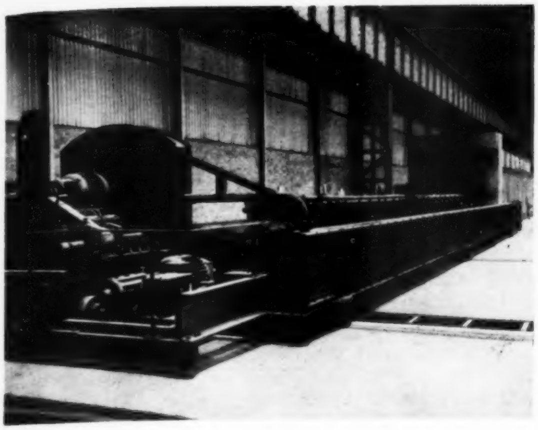
The total electrical rating required for the furnace plant is approximately 100 kW., with two ammonia dissociators, which provide the atmosphere, each rated at 50 kW. For the gas-fired part of the plant, using coke-oven gas with a gross calorific value of 500 B.Th.U./cu. ft., the ratings are 18,000 cu. ft./hr. for the flame heater and 21,000 cu. ft./hr. for the reducing furnace, giving a total of 39,000 cu. ft./hr. Honeywell-Brown gas and temperature control equipment is used throughout the line.

A number of furnaces have recently been installed for annealing non-ferrous wire, two of which may be mentioned here. The first, shown in Fig. 20, is a water-sealed furnace installed at the Ediswan Cable Works of Siemens Bros. and Co., Ltd. This furnace is 55 ft. long overall and 14 ft. wide. Fifteen gas burners on each side of the furnace fire into individual combustion chambers below the hearth, the products of combustion passing round the muffle. Coils of wire are loaded on to a chain conveyor which carries them through the water seal and



Courtesy of The Incandescent Heat Co., Ltd.

Fig. 20.—A water sealed continuous annealing furnace for treating non-ferrous wire in coils.



Courtesy of Metalectric Furnaces, Ltd.

Fig. 21.—Large box furnace and charging machine for the heat treatment of tubes.

up again into the furnace. The steam atmosphere within the muffle is maintained at a pressure of 2 lb./sq. in. The furnace and muffle are designed to work at 480° C., but in practice temperatures above 400° C. are not required. Output is 15–20 cwt./hr.

The second is a Metalectric furnace for bright annealing copper wire recently installed by W. T. Glover, Ltd. This plant, which can handle wire in coils and spools up to 1,000 lb. in weight, is automatically controlled and can be operated by one man. The wire is loaded at floor level: thus the spools are easily rolled on to the charging platform, where they are automatically tilted and placed directly on to the conveyor chains. When handling coils, however, in order that the furnace may be fully loaded at all times, the coils are not placed singly on the chains, but are stacked in carrier cages. When emptied at the discharge end, these cages are returned to the charge end by a roller conveyor. This furnace is over 100 ft. long and can operate at temperatures up to 500° C., the protective atmosphere being conditioned town's gas. The rating is 135 kW., and the consumption of electricity is 58 kWh./ton of wire annealed. Output averages between 160 and 180 tons/week.

Stordy Engineering, Ltd., are at present building an interesting furnace installation for the light metal industry. It is a coil heat treatment furnace of the regenerative type. The coil stock will be mounted on a specially designed stillage which will be progressed through the furnace by means of pusher gear. In addition to the furnace section, there are four combined preheating and cooling zones, each zone being isolated from the others by means of an insulated rising door system. Two parallel lanes are being provided, one to receive the cold work as this progresses to the high temperature zone, and a parallel lane acting as a cooling lane. Each zone is provided with its own circulating system, so that the heat released from the hot coils, as they progress from the furnace section, will be used to preheat the cold work progressing to the high temperature zone. The high temperature zone, for operating temperatures up to 500° C., is provided with four stillage spaces and a cross pusher gear to traverse the stillages to the discharge lane; this zone is provided with removable electric heater batteries and an intensive recirculated forced convection heating system. The complete system of operation is electrically interlocked so that a predetermined operating cycle must be followed.

An installation which is claimed to be the largest box furnace and charging machine in the country is in operation at the Weldless Steel Tube Co., Ltd., Wednesfield, and is shown in Fig. 21. The unit has a loading width of 6 ft. 6 in., an overall length of 140 ft., and is capable of treating 30 ton loads of steel tubes up to 60 ft. long. Work is charged into the furnace by a fully mechanised three-arm charging machine. The plant can be used for many heat treatment operations, the most important being a very closely controlled spheroidizing process, for which a programme controller is fitted to the furnace. The cycle consists of a heating-up period, followed by soaking, quick cooling and slow cooling. To enable this cycle to be accurately maintained, eight air circulating fans are fitted to the furnace, and each fan has a built-in cooling section. During the heating cycle, this cooling system is isolated, but is brought into service by the programme controller for the quick cooling period. To give the close temperature control required in this process, the furnace, which is rated at 805 kW., is divided into six separately controlled zones.

The installation shown in Fig. 22 is of the mesh-belt conveyor type, and is used for bright annealing 18% nickel silver cutlery in the Royal Dutch Gold and Silver Works at Zeist. As will be seen, the equipment is of humped back construction, the centre section being arranged to lift off to provide ease of access to the tubular elements of nickel-chromium alloy with which the furnace is fitted. These elements are arranged in two heating zones, each having its own automatic temperature controller: the total rating is 40 kW., and the maximum operating temperature 750° C. Control of speed of the belt is by Variac transformer operating in conjunction with a D.C. motor: a belt speed indicator is fitted. To

Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 22.—Mesh belt conveyor furnace for bright annealing nickel silver cutlery

Courtesy of McDonald Furnaces, Ltd.

Fig. 23.—Continuous furnace for bright annealing steel tubes.

provide the necessary atmosphere for bright annealing, an ammonia cracker is used.

Fig. 23 illustrates a continuous bright annealing furnace for steel tubes, having an output of 1 ton/hr., installed at Barton Conduits, Ltd., Walsall. A similarly designed unit, installed in the South African Works of this company, has an output of 3 tons/hr. and is rated at 750 kW. The total length of the furnace is just over 200 ft., and as no town's gas is available, the protective atmosphere is produced by a kerosene generator specially designed by McDonald Furnaces, Ltd. for this purpose.

For the patenting of steel wire, Electric Resistance Furnace Co., Ltd., have installed three controlled atmosphere furnaces at the Coatbridge works of Speedwell Wire Co., Ltd. (Fig. 24). The largest has a 4 ft. wide by 50 ft. long furnace chamber, with inlet and outlet vestibules 3 ft. 6 in. long, and is equipped with a 3,000 cu. ft./hr. exothermic atmosphere generator. The rating of this furnace is 390 kW., controlled in four zones with step-down transformers. The second furnace is slightly smaller, being 46 ft. 6 in. long and 4 ft. wide: the rating is 364 kW., controlled in four zones. Three zone control is provided on the third furnace, which is 24 ft. long by 2 ft. wide, and is rated at 100 kW.

An 80 kW. continuous wire pull-through furnace for bright annealing stainless steel tube, built by Metalectric Furnaces, Ltd., for Talbot Stead Tube Co., Ltd., is fitted with three muffle tubes, each fed with a protective atmosphere derived from an electrically heated ammonia dissociator with an output of 500 cu. ft./hr. The method of carrying the tubes through the furnace is by attaching them to endless wires which pass through each of the muffle tubes. Various sizes of tube can be handled at the same time, since the speed of each pull-through wire can be independently varied to suit the tubes to be annealed; each wire is driven from a variable speed capstan for this purpose. After heating in the annealing section, the tubes pass through water-cooled cooling tubes, and out on to the discharge table. The output from the furnace is 300 lb./hr. of tubes up to a maximum diameter of $1\frac{1}{2}$ in. and a wall thickness down to 10 s.w.g. The heated length of the furnace is 18 ft. and the cooled length 45 ft.

Carburising and Nitriding

The process of casehardening is well-known; the object is to provide components with hard surfaces to resist wear, without interfering too much with the capacity of the material to withstand other stresses. This involves the use of a carburising or nitriding medium, or the two may be combined, as in carbonitriding. For carburising, the medium may be solid, liquid or gaseous, but it is in connection with the use of the latter two media that the greater progress has been made. While the batch type of carburising furnace predominates, great progress is being made with continuous furnaces for dealing with components on a mass production basis.

Among the important developments in plant for gas carburising are the two new continuous furnaces installed at the works of the Ford Motor Co., Ltd. Both are of the gas fired, double track type, and of the same basic design, one being engaged in carburising pinions at the net output of 600 lb./hr., based on a cycle time of 20 hours, while the second is for carburising gears at the rate of 530 lb./hr.

The complete installation of the first unit consists of the carburising furnace, a washing machine and a tempering furnace, connected by a closed circuit conveyor system around which the work trays travel. Although there are fifteen separate tray movements in the whole sequence of operations, the operator has only to load and unload the trays, both at the same station. This installation is shown in Fig. 25.

The heating system, which gives a maximum temperature of 1,000° C., consists of a number of horizontal gas-fired radiant tubes with nozzle mix burners, arranged partly above and partly below the tracks on which the work trays are carried. All tubes are of the straight through type, 6 in. diameter in the heating zone, and $4\frac{1}{2}$ in. in the carburising and cooling zones, centrifugally cast in nickel-chrome alloy. The system is divided into four zones, each with automatic temperature control; the heating section forms one zone, the carburising section two zones, and the cooling section one zone. Furnace atmosphere, provided by a Birlec endothermic plant operating with butane, is forcibly circulated in the second and third zones by two powerful centrifugal

Courtesy of Electric Resistance Furnace Co., Ltd.

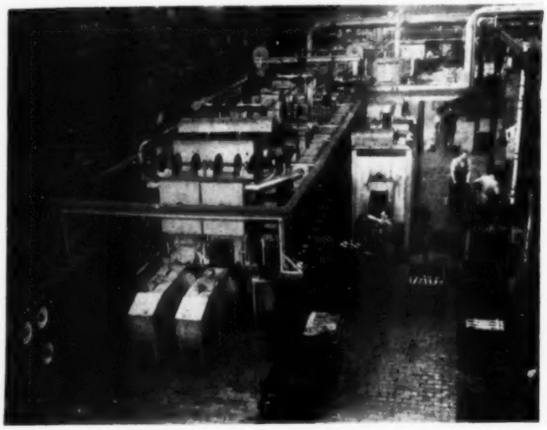
Fig. 24.—Installation for controlled atmosphere patenting of steel wire.

fans, set in the roof, to ensure uniform carburising over all surfaces of the work.

A timing clock is provided which may be pre-set to any desired time cycle allowing for a total time in the furnace of between 5 and 15 hours. After carburising at 925° C., the work is dip quenched direct from the furnace at 800° C.

Two completely automatic continuous gas carburising lines are in operation, side by side, at the works of another automobile manufacturer, with respective outputs of 600 and 450 lb./hr. of passenger car and van transmission components. The specification calls for a case depth of 0·044 in., read to 0·4% carbon, a surface carbon content of 0·9–1·1%, and a hardness of 62 Rockwell C; a specification which is readily obtained in this installation.

Each carburising line consists of a radiant tube heated pusher type continuous furnace—one line is three track and the other two track—enclosed automatic quench, washing machine and recirculating type tempering furnace. The carburising furnace and tempering furnace



Courtesy of Birlec, Ltd.

Fig. 25.—General view of the charging end of the first of the two continuous gas carburising furnaces at the Dagenham Works of the Ford Motor Co., Ltd.

are heated by producer gas. To obtain close surface carbon concentration control and maximum effective case depth, but using the minimum cycle time, a carbon "saturation-diffusion" cycle was developed in which enriched carrier gas, having a high carbon potential, is piped to the carburising zone of the furnace, whilst straight carrier gas, having a carbon potential in equilibrium with the desired surface carbon content of the work, is supplied to the diffusion zone.

The two-track gas carburising furnace, shown in Fig. 26, is equipped with a small indexing door in the back wall for the manual extraction of crown wheels which require Gleason press quenching, and a gas screen is provided through which the components are withdrawn. Through this door 24 ring gears are regularly discharged every alternate cycle in 6 minutes, and it has been found that the effect on the furnace dew point, with the small door open for 6 minutes, is almost negligible.

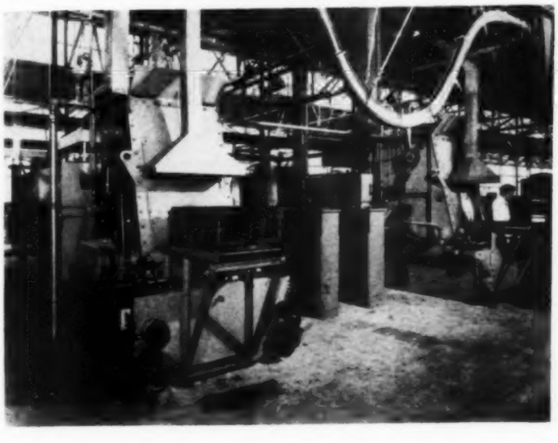
At a further factory of the same company, two continuous radiant tube heated pusher type gas carburising furnaces are installed in parallel lines, both discharging

Courtesy of British Furnaces, Ltd.

Fig. 26.—Two-track carburising furnace installation showing (left) discharge end of tempering furnace, and (right) charge end of carburising furnace.

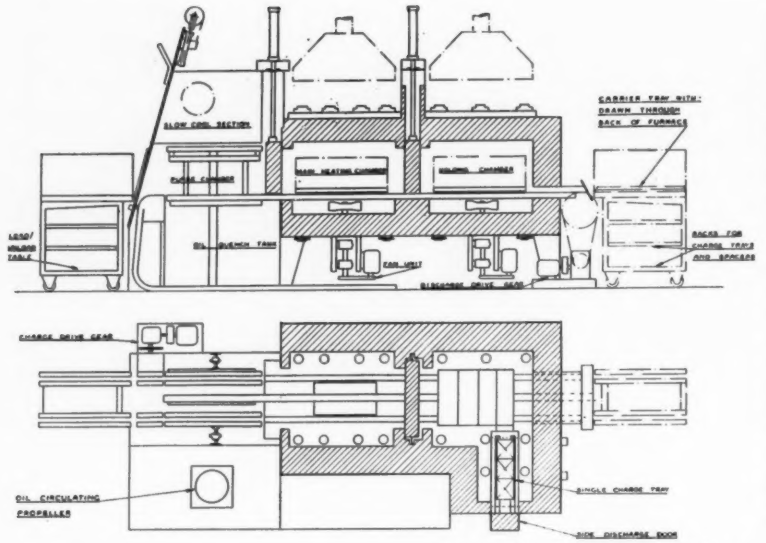
into a central washing machine and tempering furnace. The specification required is similar to that previously mentioned, but the output of one furnace is 570 lb./hr. of commercial truck transmission gears and steering gear sectors, whilst the output of the smaller furnace is 155 lb./hr. of plug and Gleason press quenched work.

Two multi-purpose closed-quench furnaces installed at the works of Morris Motors, Ltd., are shown in Fig. 27. They are horizontal type batch furnaces designed for gas carburising, bright annealing, carbonitriding, carbon restoration and annealing. The protective atmosphere, which is generated externally, is of controlled carbon potential so that steels of any carbon content can be annealed or hardened with complete freedom from decarburisation. In addition, steels already decarburised can be carbon corrected. For gas carburising, the endothermic atmosphere is enriched with propane, and for carbontitriding it is further enriched with ammonia. Each furnace has an enclosed oil quench and slow cool chamber, so that the load may be either direct quenched



Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 27.—Two multi-purpose closed-quench furnaces designed for gas carburising, bright annealing, carbonitriding and carbon restoration

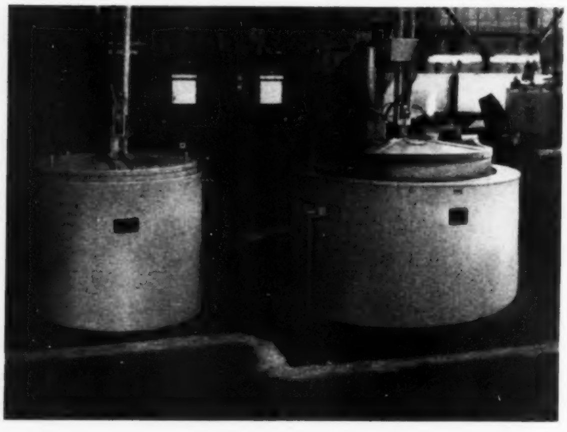


Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 28.—A line drawing of a gas fired furnace of the type shown in Fig. 27, but designed for the treatment of crown wheels and pinions, requiring individual transfer to the quenching press.

or slowly cooled out of contact with air. For gas carburising, direct quenching is often preferred ; for carbonitriding, it is standard. A lower temperature is required for carbonitriding than for gas carburising, and this lower case-hardening temperature reduces the possibility of distortion of the components treated. Where individual quenching is required, as in the case of press quenching, the unit includes a gas fired holding chamber where the parts are cooled to quenching temperature before individual withdrawal. These furnaces are standard designs and can be either gas fired, using vertical radiant tubes, or, except in the case of gas or press quenching, electrically heated, using the new Corrtherm element.

For the heat treatment of parts like crown wheels and pinions that demand a controlled cool from carburising temperature to quenching temperature, with individual transfer to the quenching press, a modification of the standard type has been developed. As will be noted in Fig. 28, a radiant tube heated holding chamber is located behind the heating chamber and separated from it by a sliding door. At right angles to this holding chamber is a heated lock chamber.



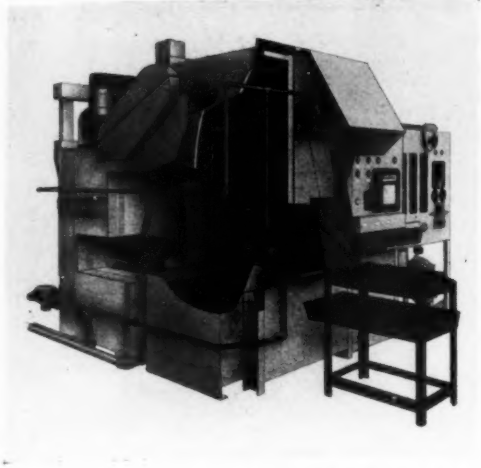
Courtesy of Integra, Leeds and Northrup, Ltd.

Fig. 29.—Homocarb equipment with Microcarb control system installed at the Jaguar Works.

Correct carburising requires control of three interrelated variables, and the results obtained depend on the accuracy with which each of these variables is controlled. Work temperature, time at temperature, and carbon potential of the furnace atmosphere are the three variables. Of these, accurate control of carbon is essential to the production of quality work. In last year's review, reference was made to the new Microcarb control system which automatically controls and records, in per cent. carbon, the potential of the furnace atmosphere. This control system is associated with the Homocarb equipment operating at the works of Rolls Royce and of the Jaguar companies (Fig. 29): it is available for use in standard batch furnaces, in a range of sizes. The introduction by Integra, Leeds and Northrup, Ltd., of the Microcarb system has broadened the scope of the Homocarb method, providing a tool for automatically controlling surface carbon on a reproducible, mass-production basis. The equipment also automatically regulates temperature in the furnace and records time at temperature. Identical loads can be run on identical settings, or cycles can be varied accurately, and the carbon range of 0·15–1·15% is wide enough for all practical applications.

Another design of multi-purpose standard batch furnace suitable for clean hardening, gas carburising, carbonitriding, and carbon restoration, is shown in Fig. 30. It is a gas-fired controlled atmosphere furnace incorporating horizontal loading and a sealed quenching vestibule, and is designed for working over a range of 400–950° C., with a uniformity of temperature within $\pm 2\frac{1}{2}$° C. through the range. It is equipped with an electronic temperature recorder and controller, process timer and electrical interlocks on the panel formed on the front of the face of the quench tank. The furnace is heated by Thermic U-shaped radiant tubes, suitable for operating in conjunction with town's gas at $2\frac{1}{2}$ in. w.g. pressure, each burner being provided with a recuperator system capable of preheating the air supply to 250° C. at the burner.

The versatile shaker hearth furnace finds application in carbonitriding, in which case a fan is provided to ensure proper distribution of the carburising atmosphere throughout the charge space. Such a furnace is illustrated in Fig. 31. With the oscillatory motion of a shaker hearth furnace, the steady processing of the work through the chamber presents difficulties if the equipment is to be versatile in its applications, unless the means exists accurately to control the tray movement, both in its oscillating rate and in its force of forward motion. Additionally, the surface of the tray itself must be



Courtesy of Thermic Equipment & Engineering Co., Ltd.

Fig. 30.—A gas-fired multi-purpose standard batch furnace for clean hardening, gas carburising, carbonitriding and carbon restoration.

formed so that it has an arresting effect to prevent work being thrown too far at each " shake " In this unit the trays are ridged from side to side over their whole length, and these ridges, in conjunction with variable speed drives and return springs and adjusters, enable close control of travel of components through the heated zone to be maintained.

Hardening and Tempering

The demand for high output is emphasised by part of the plant illustrated in Fig. 32 and built for the Scottish Stamping and Engineering Co., Ltd. It is designed to harden, quench and temper 750 crankshafts per day, and consists of two continuous furnaces, side by side, with quench tanks between. The hardening furnace is 43 ft. long, 2 ft. 6 in. wide and 6 ft. high ; the tempering furnace is the same width and height, but is 57 ft. long A notable feature of this installation is the method of handling the work. The crankshaft forgings are suspended from heat-resisting tee hangers carried by bogies running on rails along the top of the furnace : the hanger bars move through a continuous slot in the furnace roof. Each bogie has four hangers which carry eight crankshafts : this makes a unit load for handling. By suspending the forgings, a high heat transfer rate is obtained, with even heating ; moreover, quenching is very efficient, since the shafts hang freely in the quenching medium without touching each other.

The hardening furnace is under- and over-fired by low-pressure gas burners, and is divided into three temperature control zones. The tempering furnace has four zones : the first two are direct-fired by a system similar to the hardening furnace, with similar temperature control. Even greater uniformity of heating is obtained in the third and fourth zones, which are heated by separate gas recirculation units and high velocity fans, giving an accuracy of $\pm$ 2° C.

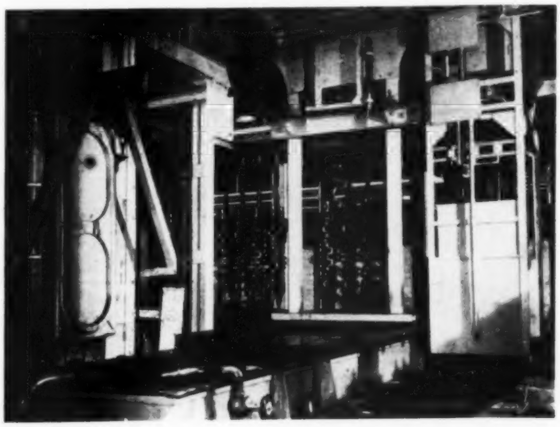
Five electrically heated circular pit-type furnaces have recently been supplied for hardening axle shafts. Each of these furnaces accommodates 32 shafts mounted upon special heat-resisting steel jigs inside a 6 ft. deep chamber, around which are mounted heating elements

Courtesy of Wild-Barfield Electric Furnaces Ltd.

Fig. 31.—Shaker hearth furnace with atmosphere circulating fan.

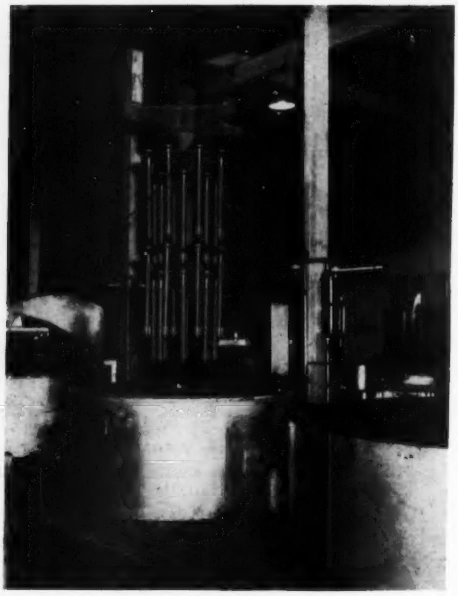
with a total rating of 145 kW. The furnaces are capable of operating at temperatures up to 1,050° C., although the normal hardening temperature is around 840° C. The average hardening cycle takes approximately 4 hours from the time of loading to the point at which the shafts are lifted out and placed in the adjacent quenching tank. One of these furnaces with a loaded jig is illustrated in Fig. 33, the quenching tank being shown in the right foreground.

The largest furnace to be constructed by A. R. Wade, Ltd., in the last year is a pit furnace having a chamber size of 22 ft. deep by 8 ft. diameter. It has been specially designed and constructed for Messrs. Joseph Lucas, Ltd. (Gas Turbine Division), for the solution treatment of Nimonic alloys. The furnace shown in Fig. 34 fulfils a dual role of air circulating age hardening furnace for temperatures up to 850° C., and solution annealing furnace for temperatures up to 1,200° C. For this latter function, the air circulating fan, which is external to the furnace, is shut down, and an insulating door is lowered to shut off the ducting from the furnace cham-



Courtesy of The Incandescent Heat Co., Ltd.

Fig. 32.—Part of plant designed to harden, and temper 750 crankshafts per day, built for the Scottish Stamping and Engineering Co., Ltd.



Courtesy of G.W.B. Furnaces, Ltd.

Fig. 33.—Showing one of an installation of five circular pit type furnaces for hardening axle shafts.

ber. It is somewhat unusual for an electric furnace of this type to be designed for operation at a temperature of 1,200° C., but this was decided upon in order to meet the possible future needs for solution annealing Nimonic 100, it being confidently expected that jet pipes of this material will be manufactured in the near future. Another furnace for the age hardening and solution annealing of Nimonic alloys—also for J. Lucas—now being constructed, takes the form of a box type furnace; this, too, will function as a dual purpose unit.

Courtesy of A. R. Wade, Ltd.

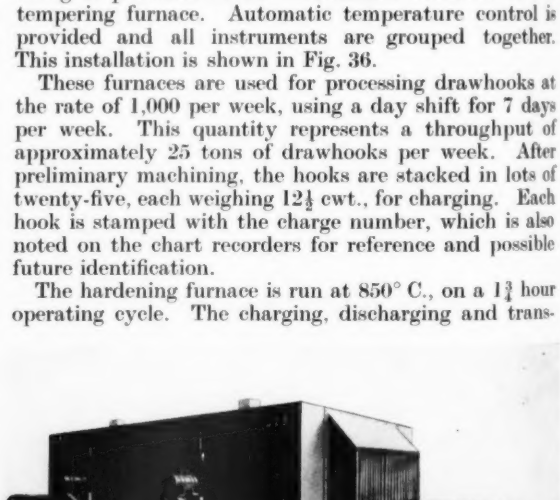
Fig. 34.—A pit furnace specially designed and constructed for Joseph Lucas Ltd. (Gas-turbine Division) for the solution treatment of Nimonic alloys.

Improvements in design of burners and control equipment, together with advances in application techniques, have enabled J. L. S. Engineering Co., Ltd., to manufacture furnaces having control characteristics more than adequate for most applications. With its adaptability, this firm's patented air circulating design is being applied to cover most heat treatment processes. Incorporated in the designs are many systems of handling, varying from the manual loading of trays to fully automatic, continuous operations, where components are discharged at pre-determined intervals, and standard monorail and belt-type conveyors are used. A typical design is that shown in Fig. 35, which is for tempering steel springs on a continuous basis, dealing with two tons of springs per hour at a maximum temperature of 550° C. Furnaces incorporating the J.L.S. air circulating system are now made for temperatures as high as 850° C., with the internal construction in heat resisting steel. A maximum differential of $\pm\ 1\frac{1}{2}$° C. throughout the working space is claimed.

A recent furnace installation is that at the works of J. & S. Eyres, Ltd., which comprises a direct oil-fired furnace for hardening, an underfired furnace for tempering, together with an oil quenching tank and an oil cooler. Both furnaces are fitted with self-proportioning oil burners and a simple type air recuperator is fitted to the hardening furnace. Full use is made of good quality diatomaceous insulating materials, and a sillimanite lining is provided in the combustion chamber of the tempering furnace. Automatic temperature control is provided and all instruments are grouped together. This installation is shown in Fig. 36.

These furnaces are used for processing drawhooks at the rate of 1,000 per week, using a day shift for 7 days per week. This quantity represents a throughput of approximately 25 tons of drawhooks per week. After preliminary machining, the hooks are stacked in lots of twenty-five, each weighing $12\frac{1}{2}$ cwt., for charging. Each hook is stamped with the charge number, which is also noted on the chart recorders for reference and possible future identification.

The hardening furnace is run at 850° C., on a $1\frac{3}{4}$ hour operating cycle. The charging, discharging and trans-

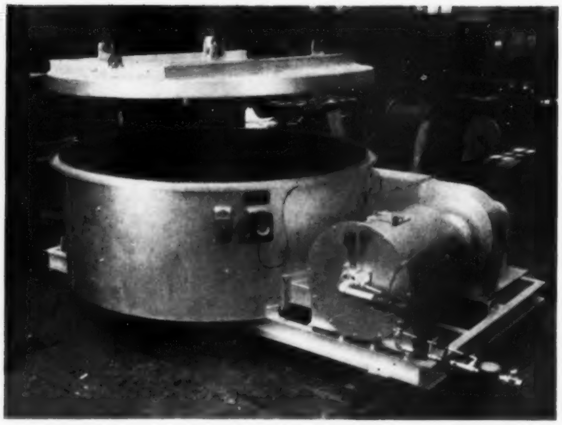


Courtesy of J. L. S. Engineering Co., Ltd.

Fig. 35.—Improvements in design of burners and control equipment are incorporated in this furnace design with its patent air circulating system.

Courtesy of Modern Furnaces & Stoves, Ltd.

Fig. 36.—A direct oil-fired furnace for hardening, an underfired furnace for tempering, an oil quenching tank and an oil cooler at the works of J. and S. Eyres, Ltd.



Courtesy of Dowson & Mason, Ltd.

Fig. 37.—A tempering furnace of the atmosphere recirculation type installed by Priestman Bros., Ltd., for tempering gear rings.

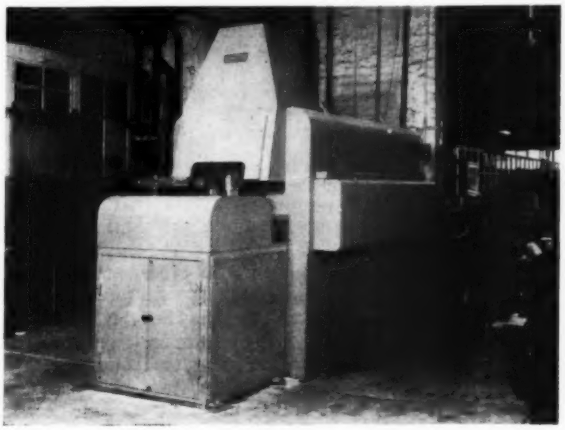
portation to the quenching tank is by a fork lift truck fitted with extra long forks to facilitate furnace charging. The time taken to discharge the furnace, move the charge to the quenching tank, and set it down on the rise and fall table, is 40 seconds. The tempering furnace is run at 660° C. on an operating cycle of 2 hours, using the standard 12½ cwt. charge. After tempering, five samples are taken from each charge and tested for Brinell hardness before the material is released for the final machining operation of threading with a 2-in. Whitworth screw thread. The fork lift truck is a novel feature of this installation, and provides an extremely flexible system of charging and discharging.

An unusual type of furnace has recently been installed at the works of Priestman Bros., Ltd. This furnace, shown in Fig. 37, is for tempering gear rings having a 4 in. square section and ranging from 2 ft. 6 in. to 6 ft. in diameter, the operating temperature being 165° C., with very close uniformity. It is of the recirculated atmosphere type, comprising a circular work chamber 7 ft. 6 in. internal diameter by 2 ft. 6 in. high, with a removable cover and a separate direct fired heater and hot gas fan. The heater is fired by two atmospheric type gas burners of different sizes, the smaller of which is constantly burning and the larger under on-off control, thus giving high-low action. Electronic type flame failure equipment is fitted, comprising probe, relay and solenoid gas valve. The removable cover of the working chamber is sand sealed at the periphery and is the full chamber diameter. The charge consists of five large rings and five small ones inside, laid horizontally, the total weight being approximately 8,150 lb.

Suitable for bright hardening and bright annealing, as well as for gas carburising and carbonitriding, the shaker hearth furnace shown in Fig. 38 is available in four standard sizes, with outputs ranging from ½ to 4 cwt./hr. It is fired by totally enclosed type wide range nozzle mixing burners suitable for consuming town's gas delivered at the normal pressure of 2–3 in. w.g. in conjunction with air at 18 in. w.g. The burners are set in refractory blocks housed in cast iron frames, for individual removal as complete units. Hearth motion is controlled by a motor driven cam and compression spring arrangement, the speed of the work being governed by a wide-range variable gear. The appearance of the furnace is improved by all burner parts, fans and operating mechanisms being enclosed within the furnace framework. It is equipped with a conveyorised oil quench, but for the treatment of long components an alternative design is available which enables the work to by-pass the normal discharge chute and pass through the furnace for off loading by hand into a quench. The furnace can also be equipped with a conveyorised cooling section for bright annealing and cooling under complete atmosphere protection.

Although the precipitation hardening of aluminium alloy is not a hardening and tempering operation in the ordinarily accepted sense, the results are achieved by a "high temperature" heating and quenching, followed by reheating at a lower temperature. Reference was made in a recent article* on the new plant for dealing with thick plate at the Rogerstone works of Northern Aluminium Co., Ltd., to a heat treatment furnace (Fig. 39) installed by Stordy Engineering, Ltd. The furnace,

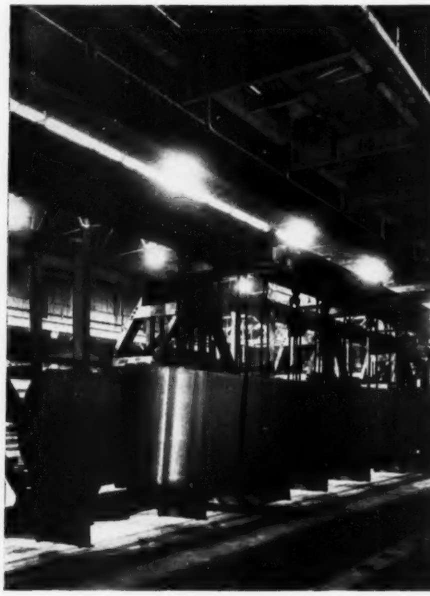
*METALLURGIA, April, 1958, **57,** 175.



Courtesy of Brayshaw Furnaces & Tools, Ltd.

Fig. 38.—Gas fired shaker hearth furnace.

which has been designed to cover the complete range of light alloy heat treatment, is capable of taking a maximum load of 20 tons for ageing treatment and for treatments not requiring quenching, and the hoist gear is rated to handle a charge load of 10 tons for solution treatments up to 550° C. with a slow quench : where high speed is required, then the charge load is reduced to 5 tons. The total electrical rating of the four heater batteries is 1,494 kW., with independent switching to provide for fine temperature control, and each of the four heater batteries is provided with its own recirculating fan. Virtually no refractory has been used in the construction of this furnace, which comprises an inner stainless steel shell backed with block insulating material. The furnace is arranged for bottom loading, and has a removable insulated lid with specially designed sealing gear. The motorised charging machine was also part of the Stordy contract.

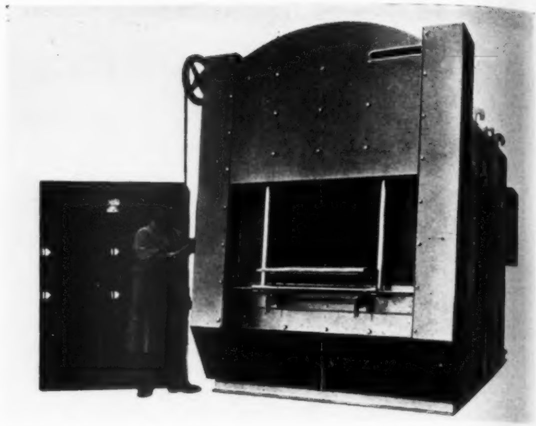


Courtesy of Stordy Engineering, Ltd.

Fig. 39.—A load of aluminium plate in charger of bottom-loading furnace at Rogerstone.

In previous reviews mention has been made of the flash annealing furnace developed by Stordy, and a most interesting development of this design is that continuous heat treatment requiring quenching is now possible. A flash annealing furnace installed on the Continent has been adapted for heat treatment with quench, and at the present time a multi-zone furnace, which ultimately may be used for heat treatment, is at present being installed in the South Wales area.

Barlow-Whitney, Ltd., have recently supplied to the Director-General, Passenger Transport Service, Baghdad, a heavy duty batch type furnace, similar to that shown in Fig. 40, for annealing and heat treatment of such things as cylinder blocks and flat leaf springs. This particular 100 kW. unit is 6 ft. long × 3 ft. wide × 2 ft. high internally, but a wide variety of sizes is available in the range. Interesting features include door heating and the provision of an automatically retractable

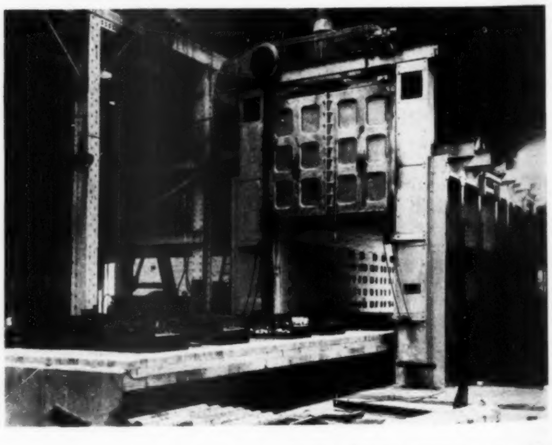


Courtesy of Barlow-Whitney, Ltd.

Fig. 40.—Batch type general heat treatment furnace fitted with retractable loading platform.

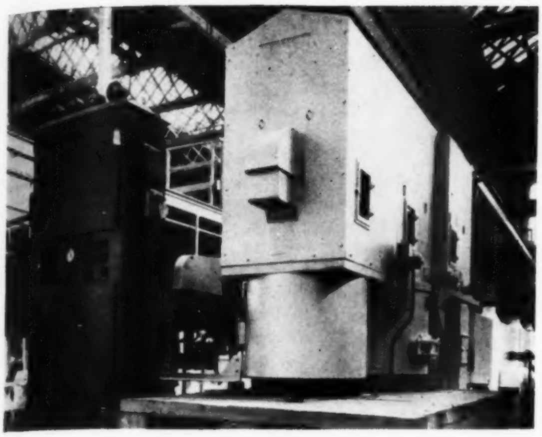
loading platform. Each size of furnace is available for temperatures up to 950° C. or 1,100° C. Special heavy nickel-chromium elements operating on standard 380/440 V., 3-phase, 50 c./s. A.C. supplies are used in the 950° C. furnaces, but the higher temperature units are equipped with heavy type resistors, fed through a suitable step-down transformer.

Heating by recirculation of hot gases generated remote from the furnace chamber to achieve extreme accuracy of temperature distribution has found extensive application in the low temperature heat treatment to rigid specifications of special alloy steels in the range 150-750° C., and Brayshaw Furnaces and Tools, Ltd., have installed several bogie hearth and oven type furnaces capable of operating up to a maximum temperature of 950° C. A bogie hearth furnace of this type is shown in Fig. 41. It has a hearth area 8 ft. wide × 25 ft. long, and a loading capacity of 50 tons. The chamber is heated by a cross flow system of heat distribution incorporating reversing valve equipment which automatically reverses the heat flow at three minute intervals, patent



Courtesy of Brayshaw Furnaces & Tools, Ltd.

Fig. 41.—Gas heated products recirculation bogie hearth furnace.



Courtesy of Imperial Chemical Industries, Ltd.

Fig. 42.—A Cassel fully automatic 15¾ by 18 gas DG furnace, built for casehardening small cycle parts.

deflectors ensuring accurate temperature distribution. The hot gases are generated from twin combustion chambers located on top of the furnace framework and recirculated by a powerful centrifugal fan via connecting ducting to the work chamber. The furnace is fitted with motor driven bogie haulage gear of the rack and wheel type, which is located in a pit below floor level, thus leaving the floor area at the front of the furnace free from any obstruction. At present under construction are three of the largest recirculation furnaces of their kind in this country, one of which has a loading capacity of 250 tons.

Salt Bath Furnaces

Mechanical methods of handling work between the various stages of heat treatment and casehardening cycles are being increasingly employed, primarily because they ensure more consistently reproducible metallurgical results. During the last twelve months, a number of totally enclosed mechanised furnaces have

Courtesy of Imperial Chemical Industries, Ltd.

Fig. 43.—A Cassel-Ajax electrode furnace, with ceramic-lined pot built for austenitising En. 31 bearing rings prior to martempering.

been supplied : among them are two Cassel DG furnaces and six Cassel CA furnaces recently supplied to Raleigh Industries, Ltd., one of which is illustrated in Fig. 42.

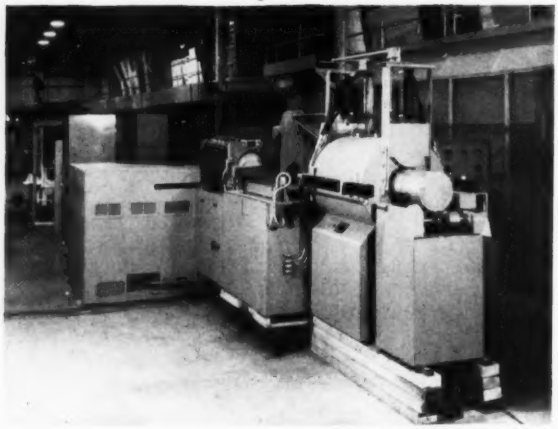
While town's gas has been the preferred fuel for externally heated furnaces, the considerable improvement effected in recent years in the design of oil burners and ancillary equipment has permitted much greater accuracy in temperature control, and many oil fired furnaces have been installed : I.C.I. report having supplied an oil fired salt bath to India for casehardening parts for jute fabricating machinery. An extension of the range of Cassel furnaces takes the form of an electrically heated salt bath furnace. The new furnaces are fitted with immersed electrodes and can be supplied with ceramic-lined pots. The working life of ceramic-lined pots, even when using " neutral " salts, is much longer than that of ordinary mild steel pots—so much longer in fact that the operation of large salt baths becomes economically worth while. The Cassel-Ajax furnace shown in Fig. 43 has internal dimensions of 58 in. by 21 in. by 20 in. deep, and is heated by means of two 75 kVA. transformers. It has been supplied for

Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 44.—An Efco-Upton graphite electrode salt bath installed in the works of Richard Carr and Co., Ltd. for the heat treatment of high speed steel tools and dies.

austenitising En. 31 bearing rings before martempering.

Another type of electrically heated salt bath has been developed involving the use of submerged electrodes. One of the difficulties of using submerged electrodes has been a means of replacing electrodes without unbricking the bath before the lining has served its useful life. The use of the Efco-Upton continuing graphite electrode overcomes this difficulty, since its replacement does not interrupt the operation of the bath. As the end within the bath burns out, the electrode is pushed further in by a screw mechanism, and when one electrode is nearly consumed another is screwed into its external end. Thus, electrode life continues for the life of the lining, which is about three years when used for neutral hardening and as long as 5–10 years for aluminium brazing : even on high speed steel work, a life of 12–18 months is achieved. Fig. 44 shows one of these graphite electrode salt bath installations in the works of Richard Carr and Co., Ltd., where it is used for the heat treatment of high speed steel tools and dies. The furnace has a rating of 120 kVA.

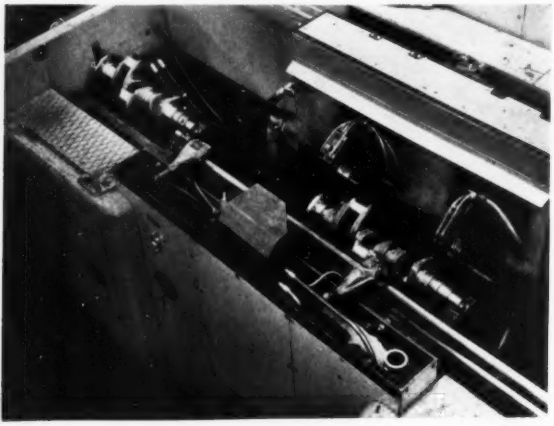


Courtesy of Electric Furnace Co., Ltd.

Fig. 45.—A new design of induction heater for aluminium billets introducing soaking chambers to ensure more uniform temperature for extrusion.

Induction Heating

Much research and experimental work has been undertaken on the application of induction heating for carrying out many metallurgical functions; this has led to the production of equipment supplied and put into operation in many works in this country and abroad. Normal frequency induction heaters for aluminium billets have been described in previous issues. In the single coil heater through which a number of billets are pushed in turn, longitudinal temperature differences occur because the billets are heated intermittently and not continuously. There are, therefore, a number of billets in the coil, at different temperatures, at any one time. To overcome this difficulty, soaking chambers have been added. This new construction, shown in Fig. 45, has two inductor coils, each with its own charging platform, and hydraulic charging ram. The two coils are charged in sequence and each is the length of one billet. The illustration shows the billet emerging from the soaking chamber ready for the extrusion press. This equipment is rated at 720 kW., has an output of $2\frac{1}{4}$ tons/hr. and is destined for the Australian Aluminium Company. Reference has already been made to the H.F. heating of the ends of bars prior to upsetting.

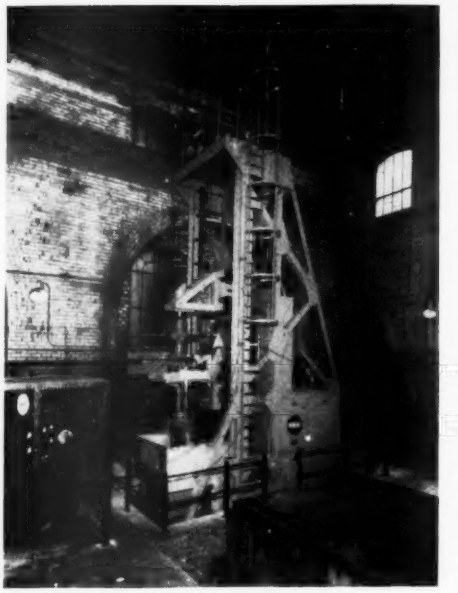


Courtesy of Electric Furnace Co., Ltd.

Fig. 46.—An automatic station for hardening crankshafts.

Crankshaft hardening and tempering equipment at the works of F. Perkins, Ltd., includes an automatic crankshaft hardening station and two cyclone vertical tempering furnaces. The crankshaft hardening station is shown in Fig. 46, one crankshaft being in the loading position and the second in the hardening position, with both inductors open. One inductor hardens the four pins, the other the three main journals. After hardening the journals in sequence, the shaft is moved to the right, where it is discharged to the rear, the carriage returning to the loading point. From the moment the crankshaft is loaded and the control button closed, the cycle is completely automatic. A 100 kW. 10 kc./s. motor generator set supplies the power.

From time to time it is necessary, on economic grounds, to regrind and reharden the outer surfaces of rolls, after they have become worn in producing tinplate and other metal strip and sheet. Since it is important to reharden only the working surface, old methods can be very troublesome. A new induction heating equipment built by Birlec, Ltd., for William Beardmore and Co., Ltd., and developed jointly by the two companies, makes an important contribution to the simplification and improved control of this tricky rehardening process. Induction heating has the advantage of selectivity, permitting the work to be heated over a clearly defined area and to a pre-determined depth below the surface, thus removing any risk of heating the roll necks or distorting their axial alignment. The machine, shown in Fig. 47, is now in operation. It is designed to handle rolls up to 18 ft. overall length and up to 32 in. diameter, supporting the work vertically between centres. The lower centre is motor driven to rotate the roll slowly



Courtesy of Birlec, Ltd.

Fig. 47.—A new induction heating machine for hardening large rolls in operation at the Glasgow Works of William Beardmore and Co., Ltd.

during hardening. The structure which supports the upper centre in guides to provide for height adjustment also carries slideways on which the heating head can be traversed over the length of the roll.

High frequency power is provided by a 400 kW. motor alternator set, operating at 1,000 c./s. Unity power factor is assured by a bank of capacitors, the value of which can readily be adjusted by switching. Alternator voltage is closely governed, irrespective of load, by an automatic regulator of a highly sensitive electronic type, which permits the heating power to be pre-set at any desired level and held constant throughout the operation. The normal procedure involves pre-heating the roll at low power, with the quench water turned off, followed by a single hardening pass over the predetermined zone. Traversing speed and power level during hardening can be set as required to produce a hardened surface of appropriate depth for each type of roll. With this machine a large roll can be preheated and hardened in about an hour. The hardness pattern can be controlled within close limits and distortion of the complete roll is negligible.

An interesting development during the year has been the application of high frequency heating for the hardening of components on one station of multi-spindle automatic lathes. By this means, additional handling of the components is eliminated and capital cost is reduced, as there is no necessity for special separate fixtures for the induction hardening. Thus components are not only machined, but also hardened in the automatic without extra labour or additional floor space. Several equipments of this type have been installed, but it should be pointed out that each application must be carefully studied to determine whether it is a practical proposition. A typical unit is shown in Fig. 48, comprising a Wild-Barfield AHF 7½ kW. H.F. generator fitted to a B.S.A. Acme Gridley multi-spindle automatic.

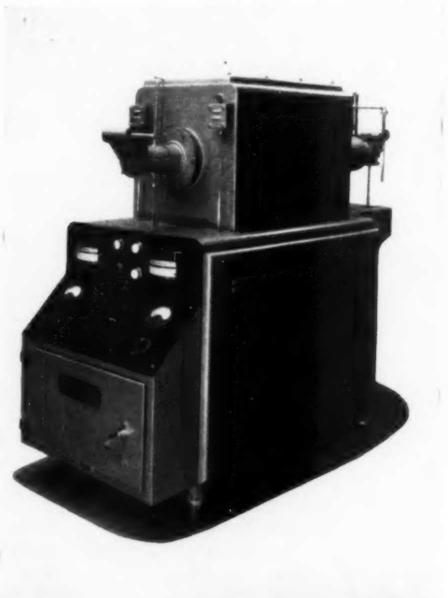
Courtesy of B.S.A. Tools, Ltd. & Wild Barfield Electric Furnaces, Ltd.

Fig. 48.—An application of high frequency heating for hardening components on one station of multi-spindle automatic lathes.

Sintering and Brazing

Many of the furnaces already briefly noted are being successfully applied for brazing, but for some purposes, higher temperatures are required than is permissible in more orthodox equipment. Mention has been made of the application of vacuum furnaces for both sintering and brazing, and a number of special furnaces of other types have also been developed for use at high temperatures. It is interesting to note, for instance, that the sintering of large compacts is now possible in a bell type furnace in the temperature range of 1,800$_2$ C. This type of furnace will probably enable powder metallurgy to play a more important part in the future by widening the scope and development of powder metallurgical products of a size not previously possible.

A typical bell type sintering plant made by Hedin, Ltd. has a hearth size 24 in. by 24 in., is 12 in. high and is rated at 40 kW. The elements are heavy section molybdenum strip, supported on the side walls and hearth of the heating chamber. The casing is made effectively gas tight and includes a gantry for lifting the furnace, making a self-contained unit. Due to the use of improved types of refractories and the experience gained in the application of these materials, there is practically no limit to the size of this type of furnace, and the cost is very little above that of an orthodox box type furnace operating up to 1,150°C. The running costs are low, particularly the consumption of protective atmosphere, and the functioning of the electrical gear eliminates a great deal of labour.



Courtesy of Sintering & Brazing Furnaces, Ltd.

Fig. 49.—A specially designed furnace for temperatures up to 1,700° C.

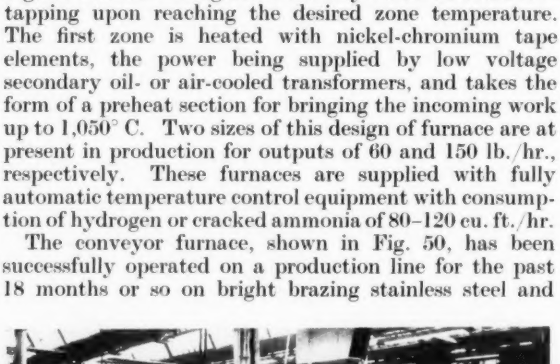
A special high temperature furnace is shown in Fig. 49; it is designed for temperatures up to 1,700° C. The heating chamber is arranged for preheating prior to the work going through the high temperature zone. In this instance also, the heating elements are of molybdenum, the electrical supply being fed via an isolation switch to

air- or oil-cooled transformers. The voltage of the secondary windings, which feed the molybdenum wound heating elements, is variable from 10 volts upwards by means of coarse and fine voltage tapping switches set in front of the control panel. The furnace is equipped with temperature controllers, and upon reaching a desired temperature a degree of proportional control is attained by the voltage of the secondary feed to the heater elements being switched automatically to a lower tapping Automatic door flushing valves are controlled via magnetic solenoid mechanism.

In an earlier issue, reference was made to a humped-back sintering furnace for temperatures up to 1,350° C.; this has been further developed by the introduction of a push-pull system by which boats are pushed and pulled through the furnace by hydro-pneumatic action. The effect of this system is to produce a point of "no load" on a pair of boats in the main heated section of the furnace and consequently a minimum of load on the rest of the boats in that section. The overall advantage is in reducing the distortion of the boats, thus prolonging their useful life and at the same time minimising the risk of "jamming" in the furnace tunnel. This push-pull mechanism is the subject of a patent specification.

The high temperature zones are heated by tubular element assemblies, spirally wound with molybdenum tape or wire, each assembly being easily removable through the side of the furnace case. A degree of proportional control is obtained in this section by the voltage of the secondary feed of the transformers supplying the elements being automatically switched to a lower tapping upon reaching the desired zone temperature. The first zone is heated with nickel-chromium tape elements, the power being supplied by low voltage secondary oil- or air-cooled transformers, and takes the form of a preheat section for bringing the incoming work up to 1,050° C. Two sizes of this design of furnace are at present in production for outputs of 60 and 150 lb./hr., respectively. These furnaces are supplied with fully automatic temperature control equipment with consumption of hydrogen or cracked ammonia of 80–120 cu. ft./hr.

The conveyor furnace, shown in Fig. 50, has been successfully operated on a production line for the past 18 months or so on bright brazing stainless steel and



Courtesy of A. R. Wade, Ltd.

Fig. 50.—Conveyor furnace for brazing stainless steel, with ammonium cracker and drying plant in the foreground.

Courtesy of McDonald Furnaces, Ltd.

Fig. 51.—Furnace for brazing at temperatures of 1,200-1,250° C.

Nimonic components. The atmosphere used is cracked ammonia, and by careful design and carefully manufactured seals, etc., it has been possible to construct a continuous furnace which will consistently produce bright stainless steel components successfully brazed. The working temperature of this unit is in the region of 1,170° C.—relatively high for a conveyor of this type. In order to attain the essential purity of atmosphere it is necessary to dry and de-ammoniate the cracker gas, and for this purpose the equipment includes a special gas drier of Wade design and manufacture.

Fig 51 illustrates the smallest of a range of standard high temperature brazing furnaces specially developed to handle new alloys requiring temperatures in the region of 1,200° C. The furnace is characterised by the special refractory hearth cover and hood, which is of refractory material and has been tested without failure at continuous temperatures of 1,250° C. Furnaces are available in both cylindrical and square sections and are now being employed for high temperature brazing with a normal working temperature of 1,250° C. The main intention of this new furnace, which is the subject matter of patents, has been to replace the very costly metallic lining by an inexpensive material which can be operated at higher temperatures to give an exceptionally long life.

Smoke Charts

MESSRS. CHARLES GRIFFIN & CO., LTD., announce that the introduction of British Standard 2742C, having a 10 cm. version of the established Ringelmann Chart does not render obsolete the Griffin 4 in. Ringelmann Chart mentioned in the Beaver Report. This chart, first produced 60 years ago and in continuous and wide use, is in fact the established commercial equivalent of the national standard.

G.E.C. Power-Operated Manipulator

Remote Handling Device

THE first general-purpose power-operated manipulator to be designed and produced in Europe, has been developed to provide remote-handling facilities in any situation where it is impossible, or undesirable, to employ a human operator. While the basic design was produced in the G.E.C. Atomic Energy Division at Erith, mainly with a view to its use in the nuclear-energy field where toxic and radioactive materials must frequently be handled, it is equally applicable, for for example, in certain chemical plants where poisonous atmospheres or hazardous processes are involved.

The power manipulator is the mechanical equivalent of a human arm and hand, although it is, in some ways, capable of a greater range of movements than its human counterpart ; in addition, it can carry heavier loads and can maintain a given psoition over long periods. To quote but a few examples of the machine's versatility, it can lift and accurately position objects weighing as much as 750 lb., handle delicate glassware without breakage, pour and stir liquids, and wield a large variety of hand and power-operated tools.

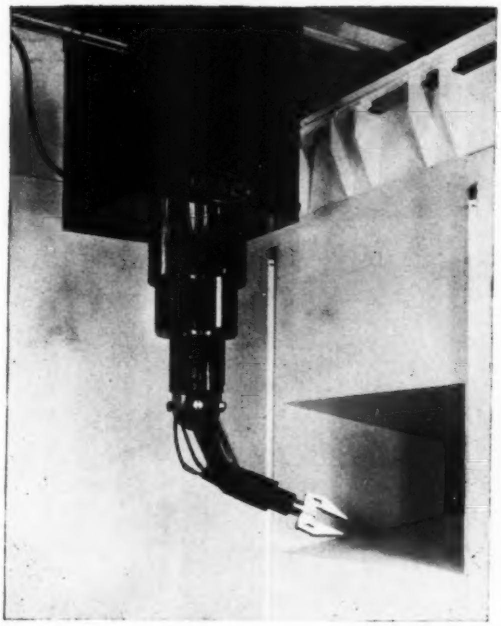
The complete operation of the manipulator is controlled by one person from a small console, which is readily moveable and can be conveniently positioned according to the viewing arrangements. Unlike the hand-operated manipulators commonly used for light handling duties, there is no mechanical linkage between the machine and the console, the only connections consisting of multicore electric cable. There is, therefore, no limitation on the distance between the power manipulator and the operator as long as some means of remote viewing, such as closed-circuit television, is available.

Basic Design Requirements

A number of important basic requirements were borne in mind at every stage in the design of the manipulator. The first of these was the necessity for complete reliability and ease of maintenance, thus ensuring the longest possible periods between overhauls, which might be complicated by the need for decontamination of the machine.

Secondly, compactness of design was desirable in order that the headroom required, and the dimensions of doors necessary for the passage of the machine from one working area to another, could be kept to a minimum. These features represent considerable economic advantages due to the high costs involved in the construction of heavily shielded cells. Furthermore, a compact, clean-lined machine is easier to cover with protective bagging and to decontaminate.

Finally, the manipulator may have to work in proximity to large sources of gamma radiation. Special attention has therefore been paid to the design of all non-metallic parts, such as electrical insulators, lubricants, and paints, which may deteriorate under such conditions.



The manipulator erected for testing in a mock-up of a cell for the handling of radioactive materials.

Mechanical Construction

The manipulator consists of a grasping device carried on a wrist, capable of continuous rotation, which is supported from a forearm, upper arm and shoulder. The arm joints are designed so that each section can rotate through 180° about its pivot, while the shoulder joint can rotate continuously about a vertical axis.

The shoulder is mounted in the base of a set of vertical telescopic tubes, the upper section of which is rigidly fixed to a crane-type carriage. This carriage can be traversed across a gantry spanning the working area and travelling on longitudinal rails mounted near the top of the walls of the cell. The gantry also supports a $1\frac{1}{2}$-ton electric hoist with a cross-traverse parallel to that of the manipulator carriage. This hoist can be used for normal lifting duties and for supporting equipment on which the manipulator is working.

The telescopic tubes, which are housed in the carriage when in their stowed position, have a positive raise and lower action, the sliding movement between tubes being taken on anti-friction bearings running on stainless steel paths. The driving motor for the tubes is mounted in the carriage.

The lowest tube houses three drive units, one for shoulder rotation, one for the shoulder pivot by which the upper arm is moved, and one for the elbow pivot which controls the movement of the lower arm. The drives to the two pivots are transmitted through sets of gears mounted in the shoulder casting, followed, in the case of the elbow pivot, by a train of spur gears inside the

Operator at control console.

upper arm. A 20-way slipring column, through which the electrical connections to the rotating section of the manipulator are made, is also housed in the lowest telescopic tube.

Mounted on the lower arm are two drive units, one for the wrist, which gives continuous rotation in either direction, and the other for the grasping device. Two such devices are normally supplied. The more versatile of these takes the form of a hand with two jaws capable of a maximum opening of 5 in. and of applying a grip-force of any value up to 150 lb. The jaws are opened and closed by means of a parallelogram linkage driven by a rack which, in turn, is coupled to the drive unit by a differential gear. The torque on the arm of this gear is used to provide an indication of the grip-pressure applied by the jaws, a spring deflected by movement of the arm being arranged to actuate a transducer.

The alternative device, which is mainly used for lifting duties, comprises a hook which can be driven against an anvil. The same drive unit is used for both the hook and the hand.

The grasping devices can be interchanged remotely. The device already attached to the manipulator is driven into a fixture which grips it firmly and, at the same time, releases a locking ring on the wrist. The wrist is then rotated until the device frees itself. The other device, which is housed in another fixture, can then be attached to the manipulator by carrying out the reverse process.

The basic elements of the manipulator can be assembled in a variety of ways to fit different sizes of cell, and can be arranged for other forms of mounting than that of suspension from a crab moving in a horizontal plane.

Electrical Drives and Connections

In the design of the electrical equipment situated inside the working area, particular care has been exercised in the selection of materials so as to ensure that the machine will have the longest possible life under the effects of gamma radiation. As far as possible, therefore, the use of organic insulating materials has been avoided.

As the operator can at all times see the manipulator, either directly or through some remote-viewing device, he is given control of the speeds of movement of the various components rather than direct control of their actual positions. He can vary the speed of each motion over a range of 8 to 1.

All the motions are powered by variable-frequency, 3-phase, squirrel-cage induction motors. This type of machine was selected on account of its rugged construction, compact size, freedom from brushgear, and the fact that no insulating material is required in the small rotors. The stator windings are of wire insulated with silicone and glass, and the slots are lined with mica. The solid insulation is made of silicone-bonded glass laminates.

The small motors used for powering the arms of the manipulator are fitted with integral electromagnetic brakes which operate from the motor flux. The brake-linings are of phenolic-bonded asbestos, which was chosen for its resistance to gamma-radiation damage. The larger motors for the long-travel, cross-traverse, and telescopic-tube drives are provided with separate shoe brakes with silicone-and-glass-insulated coils. All of these brakes are essentially for holding purposes, to ensure that there is no movement in the event of a power failure. Limit-switches are provided at both ends of the travel of each component to prevent any damage to the machine due to overrunning.

The wiring of the manipluator is carried out in a specially selected P.V.C. cable, P.V.C. being used in preference to polyethylene insulation, because it remains more flexible up to quite high gamma-radiation dosages. The connection between the head and the base of the telescopic tubes consists of a self-coiling multicore cable which is normally stored in a cylinder at the base of the tubes. Those cables that are most likely to sustain damage are equipped with plugs and sockets so as to facilitate replacement. The plugs, the sockets, and the enclosures of the motor terminals are suitable for hosing with water, while they are live, for decontamination purposes.

The structure of the 20-way slipring column in the lower telescopic tube is fabricated entirely from Micalex. The connections are made by means of silver-graphite brushes rubbing on silver sliprings, two brushes being used per ring.

The electrical supply to the manipulator is carried by a P.V.C. multicore cable resting on sheaves mounted at intervals along the side of the gantry track. A weighted take-up pulley is employed as a means of storing the cable.

Control Equipment

The variable-frequency supply for the manipulator driving motors is obtained from small motor-alternator sets which are housed, together with their associated control gear, in a separate floor-mounted cubicle. The alternators, which have a fixed excitation, are driven by variable-speed D.C. motors. Speed variation is obtained by means of magnetic-amplifier control in the armature circuits, the resulting outputs ranging from 14 to 110 volts and from 12·5 to 100 c/s. The control windings of the magnetic amplifiers are fed from potentiometers which are coupled to two joysticks mounted in the front face of the control console.

All the movements of the manipulator are controlled by means of these two joysticks. The joystick handles have simultaneous freedom of motion in four directions, each direction being associated with a corresponding movement of one of the manipulator components. The degree of displacement of the joystick is proportional to the speed of the corresponding manipulator movement. The motions of the joysticks are arranged to follow logically those of the manipulator, so that a relatively unpractised operator can control the machine with ease.

The control for the hand or hook has been designed so as to permit adjustment of both the closing speed and the grip-force. These two features are incorporated in one joystick motion so that low-grip force is associated with low speed, since a high speed of closing on to a delicate object is not a natural requirement.

The outward thrust or grip-force between the hand jaws is indicated on an instrument mounted on top of the console. This instrument is non-linearly scaled 0 to 150 lb., so that the 15 lb. graduation is in the midscale position, thus ensuring adequate sensitivity of indication when handling light or fragile objects. A further indication of grip-force is provided in the form of an audible signal from a variable-frequency oscillator, so that the operator can, when necessary, concentrate on watching the manipulator.

Switches for controlling the hoist block and for locking any of the manipulator motions in a given position are provided on the top of the console.

New High Temperature Industrial Heaters

Suitable for Direct and Indirect Heating

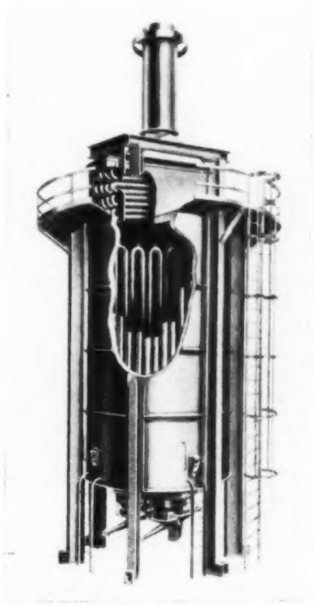
NEWTON CHAMBERS AND CO., LTD., have entered into a licence agreement with Struthers Wells Corporation, of Warren, Pennsylvania, U.S.A., for the manufacture and sale in the United Kingdom of Struthers Wells equipment designed for a wide range of industrial heating at high temperatures, i.e., in a temperature range above that of the usual steam boiler pressures. The equipment comprises a complete range of fired heaters for circulating heating systems of the Dowtherm type, in addition to those for the direct heating of process materials. Temperatures of 700° F., and even 750° F., can be obtained using Dowtherm, and with this material pressures in the circulating system, heat exchangers, etc., rarely exceed about 80 p.s.i.g. At these low pressures the thicknesses of heat exchanger tubes, tube plates and shells, and consequently the overall installation costs, are kept at reasonable levels.

Process fluids—including such materials as gas, steam, air, oils, asphalt and organic chemicals—may be continuously heated in direct fired units, and indirect heating of process equipment may be accomplished by using fired heaters and circulating thermally stable fluids. Some of the heat transfer media in this indirect heating service include Dowtherm, hydrocarbon oils of special type, Paracymene, Aroclor, and high temperature salt. In the case of Dowtherm, heat transfer can take place either in the liquid or the vapour phase. In addition to the foregoing, special equipment such as electrically heated units is also available.

Range of Sizes

Heating equipment is available in sizes from pilot plant to the largest commercial units. Where possible, the equipment is completely shop assembled and dispatched ready for installation, but larger units are assembled on site, with a minimum of labour because of sectionalised construction and simplified designs. Complete automatically controlled heating systems including instruments, safety devices, piping and other accessories are available, or the heater may be supplied as a separate unit. The type of equipment best suited for a given service may depend on a number of factors, including size of equipment, type of fuel available, thermal efficiency desired, the temperature range of heating, the thermal sensitivity of the heated material, cleanability and other considerations.

Close temperature control of industrial process heaters may be necessary for several reasons. For example, where a heater is used for process materials such as oils or chemicals, or for heating a circulating medium such as Dowtherm, the temperature range is often close to that at which the process material begins to break down due to thermal decomposition. If thermal degradation is allowed to take place, it can lead to coke formation on the tubes of the heater which, in addition to destroying the heat transfer properties of the equipment, will necessitate plant shut-downs for an extended period to enable the " coke " or other deposited materials to be removed. In other services, where a heated fluid is air, gas or steam, the tube wall is subjected to high tempera-



Section through a Struthers-Wells direct fired heater.

tures, and care must be taken to prevent damage to the metal tube. Careful study and good design of the heating equipment will avoid breakdown of materials through thermal degradation, and will also prevent damage to the heating tubes of the equipment. In fact, good design can often allow the use of lower class alloys in high temperature ranges, or, alternatively, ensure longer life.

The type of heater most commonly used is the vertical type, in which heat transfer is predominantly by radiation. For maximum thermal efficiency a bank of heating tubes of the extended surface type is commonly superposed on the vertical radiation type heater to recover the heat contained in the waste products of combustion by convective means.

Industrial Film Conference

A CONFERENCE on " The Industrial Film in Technical Education," organized by the Midland Industrial Film Association, was held on May 8th at the G.K.N. Group Research Laboratory at Wolverhampton.

The Midland Industrial Film Association was started four years ago by a group of enthusiasts representing industrial and educational interests in the Midlands, and holds regular meetings at which films are viewed and discussed. Several members of the committee attended the Industrial Film Festival at Harrogate, and came away with the conviction that although much of the film material available and being currently produced on technical and industrial subjects was admirable for public relations purposes, it was of little real use in technical education and training, a field where one would have expected the industrial film to be really useful. It is the simple, relatively inexpensive, but nevertheless carefully produced film that can often be of greatest use to the technical teacher, and it was felt that the scarcity of the right material might well be due to a lack of adequate liaison between the teachers and the sponsors and producers of industrial film.

This conference was therefore called as a first step, and aimed at clarifying the needs of the technical teacher. It was attended by principals, or their representatives, from nine Technical Colleges in the Midlands area, together with representatives from Birmingham University, the Midland Industrial Film Association and invited speakers. It was under the chairmanship of DR. T. EMMERSON, G.K.N. Group Research Laboratory Director.

Short papers were read by MR. MARRIOTT, Deputy Director of Training, Stewarts and Lloyds ; DR. N. A. DUDLEY, Head of the Department of Engineering Production, University of Birmingham ; and DR. H. I. STONEHILL, Medway College of Technology, Chatham. The discussion was opened by DR. J. WILSON, Director of Education and Training, British Motor Corporation. The main conclusions reached were :

(*a*) Although the film can never be a substitute for good teaching, it can be a very powerful aid in technical education.

(*b*) Satisfactory films for use in practically every branch of technical teaching are scarce, and the documentation in most fields is bad.

(*c*) There are many films which contain short sequences which could be of value in teaching, but since the majority of the material is irrelevant there is a reluctance to use the film, even where the existence of the vital section is known.

(*d*) It is worthwhile examining the possibility, in the broadest sense, of making more technical films of the right type available to teaching institutions. The accent should be in the first instance on the needs of the West Midlands Area.

A working group consisting of two representatives from technical education and two from the Midland Industrial Film Association was appointed with the following broad terms of reference :

(1) To examine and report on the availability of films suitable for use in technical teaching, with particular reference to the needs of the West Midlands Area.

(2) To advise on what steps could best be taken to encourage the provision of more films suitable for the purpose in mind, and to advise on the level of audience at which the need is greatest.

This group was asked to report its findings to a more widely representative meeting to be held towards the end of the year.

A.D.A. Appointments

AT the recent Annual General Meeting of the Aluminium Development Association, MR. S. E. CLOTWORTHY, (Managing Director of Northern Aluminium Co., Ltd.) was elected President of the Association for 1958/9: DR. MAURICE COOK (Chairman, I.C.I. Metals Division) was elected Vice-President. The new Chairman of the Executive Committee is DR. N. P. INGLIS (Research Director, I.C.I. Metals Division) who succeeds MR. J. H. MAYES.

The Chairman of the A.D.A. Publications Committee, MR. R. CHADWICK, has resigned and MR. E. D. ILIFF (Development Manager, Northern Aluminium Co., Ltd.) has replaced him. MR. H. M. BIGFORD, who has completed his term of office as Chairman of the A.D.A. Standards Committee, has been replaced by MR. E. G. ROBINSON (Technical Superintendent, Central Technical Department, Northern Aluminium Co., Ltd.). The Chairman of the Marine Committee for 1958/9 is MR. F. PORCHER (Development Manager, I.C.I. Metals Division).

A newly formed committee to study the applications of aluminium in chemical and nuclear engineering has been set up by the Association, and MR. E. E. SPILLETT (Development Manager, The British Aluminium Co., Ltd.) will be its first Chairman. To improve the organisation of the work of the A.D.A. technical committees it has been decided to make a new appointment of Committee Secretary. MR. K. W. BRICE, Committee Secretary with the B.S.I. for the past six years, has been selected.

Winston Export Order

WINSTON ELECTRONICS have received another order for over £70,000 from Italy for electronic equipment, which includes spectrum analysers and highly stabilised decade oscillators.

The installation at Abbey Works.

Measuring Width in a Hot Strip Mill

Servo-Driven Optical Device Uses Infra-red Radiation

THE Steel Company of Wales has recently installed an Evershed width gauge on the hot strip mill at the Abbey Works. Made by Evershed & Vignoles, Ltd., this gauge has been developed from a system put forward by the British Iron and Steel Research Association, and is a servo-driven optical arrangement for the monitoring of deviations in width in a continuous hot strip mill. It relies upon the natural radiation of infra-red rays from the strip, and is sufficiently sensitive to respond to material that has cooled to a very dull red.

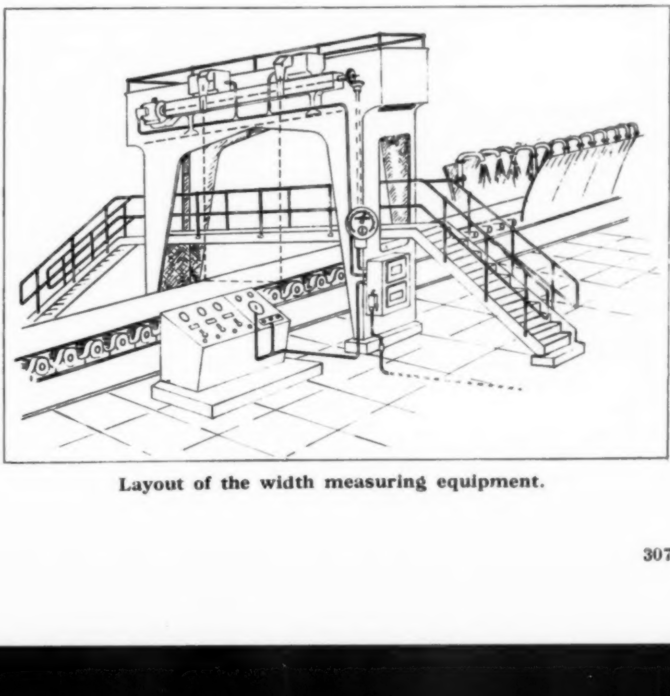
Two edge followers are used, each of which tracks the individual motions of the edges, the combined readings being summated electrically to give a signal proportional to the deviation in total width. The edge followers are mounted upon a traverse which straddles the mill a few feet above the run of strip, and are motorised so that the two may be spaced apart to a distance equal to the nominal width of strip being produced.

The method of detecting and tracing the change in edge position reduces to the minimum variations that may arise in signal strength due to fluctuations in the rolling temperature. Radiation from the surface of the strip is projected through a lens and prism on two photo-cells, placed side by side. One of the cells receives a constant amount of energy from a section of strip inboard of the edge, whilst the other is activated by the edge itself. Movement of the edge increases or decreases the radiation upon this cell, dependent upon the direction in which the strip moves. A shutter is driven across the face of the other photo-cell, reducing the radiation on it to a value equal to that obtained by its neighbour. This system of balancing radiation ensures freedom from the effects of temperature, and compensates for any changes in the characteristics of the photo-cells which might arise as a result of ageing.

Each follower is self-contained, inasmuch as it consists of an optical and photo-electric sensing device which presents a "chopped" signal to a built-in 50 cycle amplifier, the output of which drives the shutter mechanism by means of a small A.C. servo motor. Adjustable damping is provided by means of tacho-feedback derived from a small generator attached to the end of the motor. The unit operates on a 50 V. single-phase supply.

A typical layout as applicable to a wide strip mill is shown in the diagram. It will be seen that the followers are mounted on a special gantry above a foot bridge. The traverse consists of two motor-driven lead screws enclosed in an oil-filled trunk upon which the two followers slide. The motor may be seen at the left hand end, and at the right is a shaft extension which is coupled by a system of bevel gearing to an indicator for the setting of nominal width. This indicator is purely a mechanical arrangement of two pointers and dials, and is calibrated to read over the whole range of widths to the nearest $\frac{1}{32}$ in.

The small panel mounting a roll chart recorder is used for the continuous recording of nominal width and



Layout of the width measuring equipment.

deviation up to $\pm$ 3 in. One remote indicator, also calibrated to $\pm$ 3 in., is shown mounted flush in the top of the finishing operator's control desk, which also contains the nest of push buttons for control of the traverse motor. Any number of indicators may be used as the system employs conventional milliammeters wired in series, and additions may be made to the loop at any time.

Cooling of the apparatus mounted above the mill is necessary, and for this purpose a supply of water must be provided. Electrical power requirements are as follows: (*a*) to drive the gauge, 230 V. 50 cycle single phase continuous 350 W.; (*b*) to drive the traverse motor, $\frac{1}{2}$ h.p. normal rating, about 600 W., required only during changes in width setting. The accuracy of the width gauge is $\frac{1}{16}$ in.

New and Revised Standards

Glossary of Terms Used in High Vacuum Technology

(B.S. 2951 : 1958) Price 7s. 6d.

In any rapidly growing branch of technology there is need for guidance in the use of approved terms and their concepts. The purpose of this new British Standard glossary is to define the terms of accepted value in the many branches of science and industry where high vacuum technology has become important.

The glossary differs in detail from its "opposite number" in the U.S.A. but every endeavour has been made to ensure that as far as possible the same term is used with the same meaning in the two countries. Where a number of terms with approximately the same meaning have come into use, those preferred have been selected for definition. Certain terms which are redundant or deprecated have been listed separately in an appendix, along with the reasons for their non-acceptance.

The glossary is arranged in sections, dealing separately with general terms, vacuum systems, pumps and pump components, manometers and gauges, leak detectors, and vacuum applications; the last named section contains terms relating to well known vacuum processes, including electrical and valve manufacture. Comprehensive notes on pressure units, critical backing pressure and sensitivity definitions in leak detection are given in an appendix.

The new publication contains a list of the symbols and abbreviations used within its 26 pages; and ends with a detailed index to the terms defined or discussed.

55 Ton, 3% Chromium-Molybdenum Steel for Aircraft

(B.S. S.123 : 1958). Price 2s. 6d.

This new British Standard in the "aircraft" series gives requirements for material up to a limiting ruling section of 6 in. in the form of bars and billets for forging or machining and for forgings. Reference is made to British Standard 2S.100 for details of the inspection and testing procedures for the materials.

Copie of these new British Standards are obtainable from British Standards Institution, Sales Branch, 2, Park Street, London, W.1.

Pure Reagents for Trace Analysis

An increasing need for chemical reagents in quantity having extremely low limits of impurities, e.g., for use in polarography or for trace analysis, has led to the formation of an exploratory committee to investigate the possibilities of preparing specifications for such reagents. The committee is anxious to obtain as much information as possible about the limits to which impurities can be tolerated and the estimated annual consumption of reagents. All those interested in the subject are invited to write to W. J. Parker, Esq., 55, Oriental Road, Woking, Surrey, from whom a special questionnaire form can be obtained.

The exploratory committee consists of representatives of The Association of Public Analysts, D.S.I.R. Inter-Services Panel for Physico-Chemical Methods of Analysis, The Medical Research Council, Photo-electric Spectrometry Group, The Polarographic Society, and The Society for Analytical Chemistry.

New Slabbing Mill for Appleby-Frodingham

Appleby-Frodingham Steel Co., a branch of The United Steel Cos., Ltd., have placed an order worth over £500,000 with Davy and United Engineering Co., Ltd., for the supply of a new slabbing mill, which is expected to come into operation towards the end of 1959. The existing Davy 42 in. slabbing mill has been the primary rolling unit in the Appleby-Frodingham plate mills since 1926. Although still capable of meeting present requirements, the manipulators in particular are not up to the standard necessary to deal with the higher output which will be required from the mill when the company's plate mill modernisation scheme is completed next year. The new 45 in. mill will be equipped with universal manipulators and the associated roller tables are included in the order. It will be driven by the original 6,000 h.p. electric motor through the existing pinion stand. Designed to handle 15 ton ingots, the slabbing mill will have an initial production target of about 17,000 tons a week. Later, output may be stepped up to 25,000 tons a week.

Transistor Company Formed

Automatic Telephone and Electric Co., Ltd., the English Electric Co., Ltd., and Ericsson Telephones, Ltd., announce the formation by them of a jointly owned company for the development and manufacture of transistors and other semi-conductor devices. The company, to be known as Associated Transistors, Ltd., has an authorised capital of £750,000 and is constructing a factory at Ruislip, Middlesex of some 55,000 sq. ft. While the primary purpose of the company is to manufacture switching transistors for the telecommunications requirements of the sponsor companies, it will also manufacture semi-conductor devices of more general application.

British MonoRail Move

British MonoRail, Ltd., has moved to a new, modern factory in Wakefield Road, Brighouse, Yorkshire. Since its formation in 1952, the company has been at Wren Works, Chadderton, Lancashire, formerly a cotton mill. The new telephone number is Brighouse 2244 (five lines).

Reversing Rolling Mill Drives

Use of Mercury Arc Converters Demonstrated

THE use of mercury arc converters for reversing mill drives and mine winders was demonstrated recently at the Stafford works of the English Electric Co., Ltd. The Company first demonstrated the principle more than twenty-five years ago, and again in 1944, this time on a larger scale. Apart from a somewhat tentative application to machine tool drives, the practical application of mercury arc converters for this type of duty made no progress in this country until last year, when the steel and mining industries placed orders for this type of equipment.

Since the first demonstration in 1932, there have been no fundamental changes in principle, but there have of course, been substantial changes in design of the various component parts, based on the accumulated experience of their use in other fields. The processes of evolution and development have brought the multi-anode pumpless rectifier; the single anode rectifier of either the ignition or excitron type; and now the single crystal semi-conducter rectifier, using germanium or silicon. It is interesting to compare the floor space occupied by a 750 kW., 240 V. rectifier in various types. The old pumped rectifier occupied 225 sq. ft. and had an efficiency (rectifier alone) of 86·7%, the corresponding figures for an air cooled pumpless rectifier being 78 sq. ft. and 88·7%, andfor a germanium rectifier 18 sq. ft. and 96%.

Non-Reversing Drives

The general practice in large industrial reversing drives, is to have a D.C. motor supplied with a variable voltage by a motor generator set. In the demonstrations at Stafford, the motor generator set was replaced by converter equipment. Rectifier equipment has, of course, been used widely for supplying motors for non-reversing drives. The multi-anode rectifier using grid control for voltage variation has proved itself in the steel industry and for a variety of other applications. Between 1939 and 1949 a number of installations of pumpless arc rectifiers were made for steel mill drives in which contactor/resistance starting of the motors was used in combination with tap-changing and field control for speed adjustment. These have included drives for continuous billet mills and rod mills and for hot strip mills.

Fig. 1.—General view of motor room of a modern hot strip mill showing the rectifier equipment for supplying one of the roughing and all the finishing mill motors.

Fig. 1 shows the equipment for a 3,000 ft./min. hot strip mill with two 3,500 kW., 600 V. and one 1,000 kW. rectifiers. The two 3,500 kW. equipments feed the six finishing stands, whilst the 1,000 kW. unit supplies the last stand of the roughing train. The two larger units are connected to give an effective 24-phase operation, whilst the smaller unit is connected for 12-phase working. All three units are provided with grid control to maintain constant D.C. voltage up to 150% load and to compensate for A.C. voltage variations. Additionally, on the roughing stand rectifier, the voltage characteristic can be varied to provide normal voltage at light load, sloping down to give 88% at full load. Provision is made also to limit the motor current to 2·5 times full load.

Reversing Drives

For large industrial reversing drives, one of the main requirements is that the power conversion equipment shall be capable of accepting and returning to the A.C. system any power generated by the motor in braking it to rest. For maximum economy, the processes of rectification and inversion are performed by the same device and the word "rectifier" is thus no longer adequate to describe the dual function which the device has to fulfil. For this reason the phrase "mercury arc converter" has been adopted in the I.E.C. nomenclature.

In dealing with both multi-anode and single-anode devices, it is The English Electric Company's experience that, despite the physically apparent difference between them, the rival claims of one over the other for superiority of principle cannot be supported in fact. Differences are marginal and very much dependent upon the refinement of detail which arises from experience. Since the weight of experience lies with the multi-anode tank, this type of converter was used for the demonstrations at Stafford.

In considering the design of the converter tank, the requirements for good inversion are not significantly different from those for good rectification under grid control. If the tank will work well as a grid-controlled rectifier it can usually be relied upon to work equally well as an inverter.

In many industrial drives the working peak currents are much larger than the rated R.M.S. and average currents, and in order to meet these conditions the tank shown on Fig. 2 was developed. It incorporates recent developments on the lines of improved cooling and of increased arc path area to reduce arc drop and to provide reliable operation under heavy peak currents when cold.

The fundamental requirements of a large reversing drive are :—

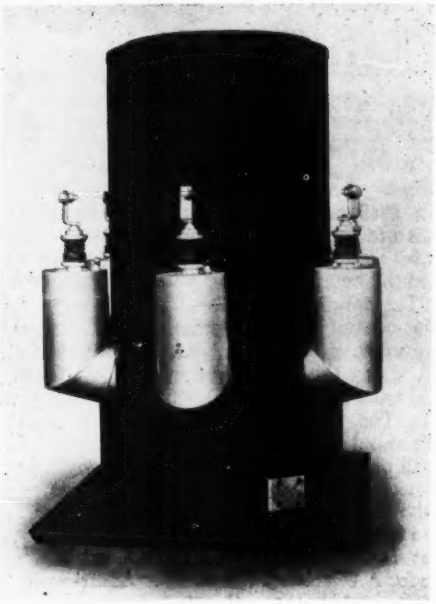


Fig. 2.—Typical industrial multi-anode steel tank rectifier.

(1) To run the motor up to normal speed from rest under gradually increasing voltage.

(2) To brake the machine to standstill, feeding the energy back to the A.C. system at a controlled rate. In certain applications the motor may be brought to rest sufficiently rapidly by the load itself without the need for regenerative braking.

(3) To run the motor up to speed in the reverse direction by gradual increase of voltage.

When using mercury arc converters a choice of three methods of meeting these requirements is open, namely, by the use of cross-connected converters, by armature reversal or by field reversal.

Cross-connected converters (Fig. 3) entail the use of two sets of converter equipment, permanently connected to the machine bars. One acts as the rectifier for forward rotation and as an inverter for braking when running in reverse rotation. The other performs the same function for contra-rotations. This circuit avoids the reversal of either motor flux or motor armature. There is thus, negligible " dead " or " lost " time at the point of changeover from motoring to braking. Such an arrangement is necessary when rapid and continuous speed control of high-inertia drives is wanted. Usually it is no more expensive in first cost than an equivalent motor-generator set and, of course, retains the efficiency advantage of converters.

With the somewhat less exacting requirements of reversing mills and some winders where a short period of " dead " time (say 0·3 sec. or longer) is tolerable, some saving in first cost can be accomplished by employing the same converter for both motoring and braking duty. Because the mercury arc converter can pass current in one direction only, it becomes necessary to reverse the motor polarity when changing from motoring to braking. This can be accomplished either by reversing the armature connections or by reversing the motor field.

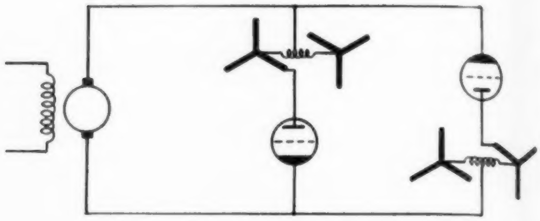


Fig. 3.—Cross-connected converter system.

With armature reversal (Fig. 4), at the instant when it is desired to initiate braking, the grid impulses are phased back to the position for maximum inverter back e.m.f.; this interrupts the motor current and the armature connections are then reversed by means of the reversing switch. When this operation is complete, the phase position of the converter grid impulses is advanced to reduce the inverter back e.m.f. to a suitable level to allow braking current to flow. By continuous advance of the grid phase angle the motor will come to rest and, if the phase advancing be continued, can be brought up to speed in the reverse direction.

With field reversal (Fig. 5), the procedure is similar except that, if desired, the inverter e.m.f. can be reduced to allow braking current to flow as soon as the machine e.m.f. has reversed. The inverter back e.m.f. is controlled at the level which provides the requisite braking current until the motor is at rest. Reverse rotation of the motor is obtained by further advance of the grid phase position.

So far as concerns operation, the principal difference between the two methods lies in the fact that armature reversal can be made slightly faster than field reversal. The value of this time advantage depends upon the application ; for example, it can be of greater interest in steel mills than to colliery winders.

Armature reversal involves the use of a relatively heavy current reversing switch which, however, does not have to break current. It must, of course, be capable of withstanding frequent operation. With field reversal there is associated the problem of reversing a small current in a highly inductive circuit, and of building up that current in the reverse direction as quickly as possible. The use of laminated frame D.C. machines assists materially in reducing the flux reversal time.

Advantages of Converters

For reversing drives in steel mills, it has long been common practice to employ D.C. mill motors fed from motor-generator sets, sometimes driven by synchronous motors, but more often by induction motors, frequently using a flywheel to smooth out the heavy load peaks. The synchronous motor driven generator set provides the facility for power factor correction which the mercury arc converter lacks. On the other hand, peak loads suddenly imposed on the D.C. motor result in load overswing on the A.C. system due to the inertia of the synchronous motor. This may well amplify the peak load demand to a level where it results in undesirable voltage dips on the A.C. system.

In this respect the mercury arc converter occupies an intermediate position between the synchronous motor set and the flywheel or Ilgner set. The mercury arc converter simply reflects on the A.C. system an accurate reproduction of the load. Due consideration must,

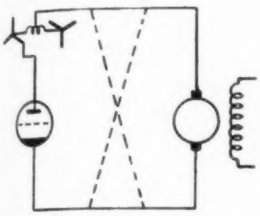
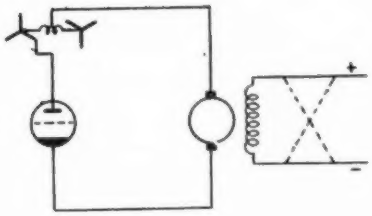


Fig. 4. (left)—**Armature reversal system.**

Fig. 5. (right)—**Field reversal system.**



therefore, be given to the A.C. system when applying mercury arc converters to ensure that voltage dips coinciding with load peaks are within tolerable limits. Harmonic currents arising from mercury arc converters can usually be satisfactorily dealt with by phase multiplication, the need for which is determined by the size of the converter in relation to the size of the A.C. system feeding it.

With an A.C. system of adequate capacity, the mercury arc converter in general shows the following advantages over the motor-generator set for rolling mill drives :—

(1) Lower in first cost.

(2) Less expensive in foundation and installation costs.

(3) More efficient over the normal working range of load.

(4) Lower light load losses.

(5) Lower maintenance cost.

(6) The converter does not add to the fault level of the A.C. system.

(7) Less noisy.

There appears to be a case for the consideration of mercury arc converters for reversing steel mill duty, on both technical and economic grounds. The motor-generator set equipment has proved itself very reliable in service, and any advantages which the mercury arc rectifier might have would be nullified if the system were unreliable. On the basis of the extensive experience gained in recent years in the use of rectifiers, it is believed that mercury arc converter equipment can be made equally as reliable as the motor-generator set.

Reference has been made earlier to the effect on the supply system of the use of mercury arc converters for this type of work. The extent to which they are adopted will largely be determined by the attitude of the supply authorities, who seem to be somewhat conservative when compared with their counterparts on the Continent and in the United States. It is believed, however, that a satisfactory solution to this problem can be achieved by co-operation between manufacturer, user and the supply authorities.

Light Alloy Water Tanks for Tankers

TWO of the largest light alloy tanks ever made in Great Britain, and believed to be the largest tanks ever prefabricated for marine use, have been built by Windshields of Worcester, Ltd., entirely of $\frac{1}{4}$-inch MG5 aluminium alloy plate and extrusions made by James Booth & Co., Ltd., of Birmingham.

The tanks are to hold fresh drinking water aboard two Caltex oil tankers being built in Belgium. They are to be installed topsides, and the use of the MG5 is therefore of great importance in saving superstructure weight. In addition, the water will store better and traditional troubles due to scaling, rusting and tank cleaning will be obviated. Similar light alloy drinking water tanks may well become standard in future vessels throughout the world.

The first of the two tanks to be completed is approximately 18 ft. × 14 ft. × 7 ft. and weighs approximately 4-tons. It left the factory on May 2nd and proceeded with a police escort on a low-loading transporter via a special route to Tilbury for shipment. The second tank, approximately 30 ft. × 12 ft. × 5 ft. and weighing about 4-tons 3-cwt., followed the same route a fortnight later.

The tanks are Argonaut welded throughout, every weld having been subjected to exhaustive tests. Each tank is divided internally into two separate compartments holding 25-tons of drinking water, thus giving each ship storage for 50-tons of water in the new type of tank. The nominal capacities of the tanks are, 11,200-gal. and 11,420-gal. respectively.

They are to be fitted into the bridge space of the two new tankers *Caltex Cardiff* and *Caltex Bristol* each of 32,000 tons deadweight, being built by S. A. Cockerill Ougree of Hoboken, Antwerp, Belgium, for Overseas Tankships (U.K.), Ltd., an affiliate of the Caltex group. *Caltex Cardiff* is to be delivered during the current year and *Caltex Bristol* is scheduled for mid-1959. The engineers of Windshields and the metallurgical staff of James Booth, worked in close co-operation with the Belgian ship-builders on all design problems.

One of the tanks leaving the makers' works.

NEWS AND ANNOUNCEMENTS

The Institute of Metals

New Officers

The following members have been elected officers to fill vacancies on the Council of the Institute of Metals :

President: MARSHAL OF THE ROYAL AIR FORCE LORD TEDDER, G.C.B., D.C.L., LL.D. (Chancellor of the University of Cambridge; Chairman, The Standard Motor Co., Ltd.).

Vice Presidents: MR. G. L. BAILEY, C.B.E. (Director, British Non-Ferrous Metals Research Association); MR. R. D. HAMER (Vice-President and Director, Aluminium Laboratories, Ltd.); and SIR RONALD PRAIN, O.B.E. (Chairman, Rhodesian Selection Trust, Ltd., Roan Antelope Copper Mines, Ltd., and Mufulira Copper Mines, Ltd.).

Members of the Council: THE HON. G. CUNLIFFE (Deputy Chairman and Managing Director, The British Aluminium Co., Ltd.); DR. L. B. HUNT (Manager, Industrial Division, Johnson, Matthey and Co., Ltd.); LORD KIRKWOOD of Bearsden (Director, Imperial Smelting Corporation, Ltd.); MR. W. F. RANDALL (Managing Director, Metals Group, Telephone Construction and Maintenance Co., Ltd.); and MR. F. W. TOMLINSON (Managing Director, Pyrotenax, Ltd.).

Award of Medals

The Council of the Institute has made the following awards of medals for 1958 :

The Institute of Metals Medal in Platinum to PROFESSOR EMERITUS R. S. HUTTON, in recognition of his outstanding work in connection with the science and practice of non-ferrous metallurgy.

The Rosenhain Medal to DR. J. H. HOLLOMON, in recognition of his outstanding contributions to knowledge in the field of physical metallurgy.

City and Guilds Courses

Metallurgical Technicians

The City and Guilds of London Institute has been asked to explore the possible need for courses for what have been described as " metallurgical technicians." It has been suggested that a gap exists between the level of the Operatives' courses on the one hand and the Institute's existing scheme in Metallurgy, or the Ordinary National Certificate in Metallurgy, on the other. Investigation into the matter is now being undertaken by the General Advisory Committee for Metallurgical Subjects, together with representatives of other organizations which are interested.

Qualifications in Iron Ore Mining

There has been a substantial growth in the demand for British iron ore during the last fifteen years, but there has so far been no nationally accepted qualification available to the majority of those employed in the industry. The need for qualifications has been accentuated by the Mines and Quarries Act, 1954, which came into force on January 1st, 1957, and the National Council of Associated Iron-Ore Producers recently invited the co-operation of the Institute in providing possible certification for certain grades of people employed in the industry. An exploratory committee has therefore been formed to look into the possibility and desirability of drawing up a scheme of examinations.

Technical Authorship

The Institute's Exploratory Committee has reported that there is an urgent need for courses and examinations in technical authorship, that technical writing can be taught in technical colleges, and that examinations in the subject can be conducted by the Institute. The committee has therefore prepared a scheme of syllabuses and examination arrangements, and the first intermediate and final examinations will be held in 1960 and 1961, respectively.

Institution of Metallurgists

THE Annual Luncheon of the Institution took place on Tuesday, 20th May, 1958, at the Park Lane Hotel, Piccadilly, London, with the President, Mr. W. E. BALLARD, in the chair. The principal speakers were SIR GILBERT FLEMING, K.C.B., Permanent Secretary, Ministry of Education, and MR. A. G. STEWART, Chairman and General Managing Director, Stewarts and Lloyds, Ltd.

Other distinguished guests included LORD and LADY KIRKWOOD; LT. COMDR. CHRISTOPHER POWELL, Secretary of the Parliamentary and Scientific Committee; MR. S. E. CLOTWORTHY, President, Aluminium Development Association, and MRS. CLOTWORTHY; MR. J. B. DENNISON, President Institution of Mining and Metallurgy, and MRS. DENNISON; DR. T. P. HOAR, President, Institute of Metal Finishing; MR. A. R. MATHIAS, Chairman, Lead Development Association, and MRS. MATHIAS; MR. A. A. PART, Under Secretary (Further Education), Ministry of Education, and MRS. PART; MR. R. T. DE POIX, Chairman Zinc Development Association; and DR. G. B. B. M. SUTHERLAND, Director of National Physical Laboratory, and MRS. SUTHERLAND

Honorary Members of the Iron and Steel Institute

IT was announced at the Annual General Meeting of the Iron and Steel Institute on May 7th, that H.M. King Baudouin, King of the Belgians, and H.R.H. Charlotte, Grand Duchess of Luxembourg, had graciously accepted Honorary Membership of the Iron and Steel Institute. They are joint Patrons of the Institute's Special Meeting in Belgium and Luxembourg, which is being held from June 18th to 28th, in conjunction with the Journees Internationales de Siderurgie, being organized in connection with the Brussels World Exhibition.

Productivity Film Catalogue

THE British Productivity Council has found the film one of the best mediums for " putting across " both the need for raising productivity and practical appreciation of new techniques and methods for increasing output. B.P.C. films have dealt effectively with emotional subjects like " restrictive practices " and " resistance to change " and technical subjects like work measurement and production

control. An important factor in their success has been that in dealing with controversial subjects, or techniques in which some conflict of interest may be involved, these films represent the joint views of employers and trade unionists. The films explore and depict the ground common to both " sides " of industry, and have done a great deal to show how extensive the area of agreement is on matters affecting efficiency and high output.

The total audience reached by the films is difficult to estimate, but they are being shown at the rate of 15 times each working day throughout the year. The B.P.C. has now produced a catalogue of the films with descriptive notes. Copies of films can be bought from the B.P.C., 21 Tothill Street, London, S.W.1. or hired from the Central Film Library, Government Building, Bromyard Avenue, Acton, London, W.3.

Cybernetics Periodical

THE International Association for Cybernetics will publish from May 1958, a quarterly review called *Cybernetica*, containing articles of a scientific nature on subjects relating to the various domains of cybernetics. Each number will feature an average of four articles on varied subjects. Whenever there is sufficient material there will be a special section called " Recent Publications " dealing with articles and other works connected with cybernetics. One page will be devoted to news of the activities of the International Association for Cybernetics. Articles will be published in French or in English, according to the wishes of the author.

The subscription for 1958 has been fixed at 300 (Belgian) francs, and at 150 francs for the members of the International Association for Cybernetics. Separate numbers of the review may be obtained at 100 francs each, and at 50 francs for the members. Subscriptions should be sent to the International Association for Cybernetics, 13, rue Basse Marcelle, Namur (Belgium).

New Iron and Steel Import Duties

A NEW Import Duties Order, entitled The Additional Import Duties (No. 3) Order, 1958, came into operation on April 28th, 1958. The order, which implements the agreement with the European Coal and Steel Community signed last November, has the effect of reducing the United Kingdom import duties on the main crude and semi-finished products of iron and steel and certain forms of finished steel to 10% *ad valorem*, with appropriate adjustments to the alternative specific rates of duty. The suspension of duty on certain products until September 18th, 1958, will not be affected by the Order. Copies of the Order (S.I. 1958 No. 671) may be obtained from Her Majesty's Stationery Office, or from any bookseller, price, 3d. (by post 5d.).

New Journal on Wear

A new international journal on the fundamentals of friction, lubrication and wear, and their control in industry is being produced by the Elsevier Publishing Co., Amsterdam. The first three issues (August, October and December, 1957) and the titles of papers now being prepared for publication give a fairly clear picture of the field of wear research, ranging from physical-theoretical studies to industrial aspects. Original papers as well as critical review articles deal with functional properties and wear resistance of metallic, inorganic and organic materials under laboratory and working conditions. This exchange of knowledge in English, French and German between experts from Australia, Japan, India, the Soviet Union, U.S.A. and Europe, is supplemented by a compact section containing abstracts and brief reports on current events.

Phosphating Processes Approved

ATRAM Phosphating Processes A, B, C, F55, and O.S. have been tested by the Ministry of Supply Inspectorate of Armaments in accordance with Inter-Services Defence Specification DEF-29, and also to long-term tests in salt spray testing apparatus (cabinet) conditions, as distinct from the salt droplets spray test of this specification. All the tests were satisfactory and the following gives the classification of the processes as determined from the test results and the phosphate coating weights :

Designation of Process	*Type of Process*	*Class*
Atram A ..	.. Manganese Unaccelerated	I
Atram B ..	.. Manganese Accelerated	I
Atram C ..	.. Zinc accelerated	II
Atram F55	.. Zinc accelerated	III
Atram O.S.	.. Complex Iron Phosphate accelerated (cold process)	III

This classification is in accordance with Inter-Services Defence Specification DEF-29.

British Stainless Steel Rail at Brussels

IN anticipation of the heavy vehicular traffic at the Brussels Exhibition, the Belgian government have had guard rails erected at certain of the pedestrian crossings. The utilitarian aspect has not blinded the authorities to the aesthetic requirements of such a feature, and a contract to supply rails from polished austenitic stainless steel was awarded to Rollo-Hardy & Co., Ltd., Blaenrhondda, Glamorgan. More than 50,000 ft. of rail was provided for local contractual fabrication, in two sizes of rectangular welded stainless steel tubes, using Silver Fox stainless steel strips, Type S.F.620, the value of the contract being in the region of £25,000. Rollo-Hardy is a subsidiary of the Compoflex Group of Companies.

Materials Handling Films

THE National Joint Committee on Materials Handling, a co-ordinating committee for professional and other bodies interested in materials handling, particularly from an educational standpoint, has compiled a list of films on materials handling, which is now available upon receipt of a stamped addressed envelope, from The Secretariat, National Joint Committee on Materials Handling, 20/21 Took's Court, Cursitor Street, London, E.C.4. Some sixty titles are listed, showing the size and running-time (where known) the source of the film, and a brief synopsis of its purpose and audience suitability. The need for and value of better handling methods in British Industry is amply demonstrated in many of the visual aids catalogued.

Oxygen Plants Near Completion

THE new British Oxygen Linde tonnage oxygen plant being erected at Shell Haven on the Thames Estuary by British Oxygen Engineering, Ltd., is expected to be commissioned in August. It is designed to produce

240 tons of oxygen and 235 tons of nitrogen a day for the manufacture of ammonia. Another British Oxygen Linde plant, being built at Partington, Lancashire, for Petrochemicals, Ltd., will be capable of supplying 145 tons of oxygen and 55 tons of nitrogen a day. The oxygen will be used for the direct oxidation of ethylene, and this plant is also expected to come into service in August. The combined value of the contracts for these two plants is estimated to be more than £500,000.

Personal News

THE Chairman and Directors of Crofts Engineers (Holdings), Ltd., announce the appointment of MR. G. HORSLEY to the Board of the Company, and also his appointment as Joint Managing Director of the operating company, Crofts (Engineers), Ltd. MR. F. O .ACKROYD, has been appointed to the Board of the latter Company.

MR. G. WRIGHT, London Manager of the Incandescent Group has been making an extended market investigation in India. The Group has had a long association with India, and Mr. Wright will report on the new openings for capital goods in this rapidly expanding market.

WILLIAM JESSOP & SONS, LTD., and their associated company J. J. Saville & Co., Ltd., announce that, following the death of MR. F. BRIGGS, the late Secretary of these Companies, MR. D. MILNE, has been appointed Secretary, and MR. J. V. GREGORY Assistant Secretary.

SIR THOMAS R. MERTON, K.B.E., F.R.S., having reached normal retirement age, has left the Board of Vickers, Ltd., and SIR SAM H. BROWN has been appointed an additional Director.

THOMPSON BROS. (BILSTON), LTD., of Bradley Engineering Works, Bilston, announce the appointment of MR. E. E. PHEASEY, M.B.E., as Works Director. MR. PHEASEY was previously with Foster, Yates & Thom, Ltd.

MR. T. F. W. JACKSON has been appointed Chairman and Managing Director of Union Carbide, Ltd., in succession to MR. W. B. H. GALLWEY who died last December.

MR. R. C. HESKETH-JONES, formerly Sales Director (Industrial Division) of British Oxygen Gases, Ltd., has been appointed Chief Executive (Overseas) at the Head Office of The British Oxygen Co. MR. R. J. FOSTER, D.F.C., A.F.C., who has recently been Director and General Manager of British Oxygen Aro Equipment, Ltd., succeeds MR. HESKETH-JONES. CAPT. Q. P. WHITFORD, O.B.E., R.N. (Retd.) who is taking charge of the Aircraft Equipment Works at Harlow, will be closely linked with the activities of British Oxygen Aro Equipment, Ltd.

THE BRITISH IRON & STEEL RESEARCH ASSOCIATION announces that MR. S. S. CARLISLE, Head of the South Wales Laboratories since February, 1954, has been appointed Head of the Physics Department at BISRA's Battersea Laboratories. In addition he will continue to have an executive responsibility for the South Wales Laboratory as Deputy Head of the Mechanical Working Division (Swansea). He is to be succeeded at Sketty Hall by MR. W. N. JENKINS, of the Electrical Engineering Section of BISRA's Plant Engineering Division at Battersea. Both these appointments are operative from 1st July, 1958.

MR. P. A. HEARNE has been appointed Sales Manager of British Oxygen Aro Equipment, Ltd. He succeeds MR. D. INCE, who is taking up an appointment as Divisional Manager of the Guided Weapons Division of Elliot Brothers (London), Ltd.

TUBE INVESTMENTS, LTD., announces that MR. A. J. S. ASTON and MR. R. D. YOUNG have been appointed to the Board. Both MR. ASTON and MR. YOUNG have served the Group for many years in senior executive capacities.

MR. L. F. COOKE, formerly Head of the Industrial Sales Department, has been appointed Commercial Sales Manager of Cambridge Instrument Co., Ltd.

MR. J. CROWLEY has retired from the position of Assistant Sales Manager of Edgar Allen & Co., Ltd. at the age of seventy, after fifty-six years service. MR. L. LAMPLUGH, who joined the Company last November has been appointed Sales Engineer to the Engineering Department.

MR. C. A. FLINT has been appointed Secretary of Sparklets, Ltd., and MR. J. B. SHOTT Chief Accountant.

MR. R. E. NORMAN, who has been Secretary of the Hughes Bolckow ShipbreakingCo., Ltd., of Blyth, Northumberland, since 1953, has been given the additional appointment of Assistant General Manager.

MR. C. BATES, Technical Director of Welding Supervision, Ltd., recently made a four week tour of Pakistan and the Middle East, during which he surveyed work carried out by W.S.L. teams on the Sui-Multan gas link-line.

Obituary

We regret to record the deaths of the following :

MR. A. H. WAINE, a Director of Hadfields, Ltd., and Managing Director of Hadfields Forgings, Ltd., who died in Brussels on Sunday, 4th May, 1958, while on a business tour of Germany, Holland and Belgium. Mr. Waine, who was fifty-seven, had been with Hadfields, Ltd., for over forty years. In 1945, when he was Manager of the Heat Treatment Department at both Hecla and East Hecla Works, he became a Local Director of Hadfields, Ltd. During 1948 he was invited to join the Board of Hadfields Foundry and Engineering Co., Ltd., at the same time acting as the Technical Manager of that Company. He was elected to the Board of Hadfields, Ltd., in 1950. Among his special interests were steel supplies for ordnance and hardened steel rolls.

MR. P. H. MUIRHEAD, C.B.E., who died on Sunday, 27th April, 1958, at the age of fifty-three. Until his resignation for health reasons last January, he was Managing Director of Vickers-Armstrongs (Engineers), Ltd., and a Director of Vickers, Ltd., and of other companies. Mr. Muirhead joined the Elswick Works in 1927, in the Estimating Department, subsequently becoming Manager of Commercial Products. In June, 1941, he was appointed a Special Director, and in 1944 became Deputy General Manager, Elswick, Scotswood and Chertsey. He became Director and General Manager in 1945 and Managing Director (Engineering Division) of Vickers-Armstrongs, Ltd., in 1953.

MR. J. H. PAWLEY, a Director of George Cohen, Sons & Co., Ltd., who died on 15th April, at the age of 78. Mr. Pawley joined the Company fifty-one years ago and up to last December was in personal, day-to-day control of the firm's dismantling activities—involving every year the negotiation and general supervision of hundreds of major contracts in Britain and overseas.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

High Speed Guillotine

THE new Keetona 8 ft., $\frac{1}{8}$ in. guillotine, model 96/125 has an extra wide bed of box type construction designed to give maximum rigidity and freedom from deflection. Maximum rigidity is obtained by the robust design of the bed and the end frames into which it is fixed, and adjusting screws at each end of the bed ensure accurate and easy adjustment of the blades after regrinding. The cutting beam is a heavy cast triangular section, ribbed internally to eliminate all risk of springing during the cutting stroke, and to ensure straight, accurately sheared material. The design of the automatic spring hold-down beam allows the operator a clear view of the cutting line. It is fitted with long rubber pads to ensure a positive grip and to obviate creep during the cutting operation. When the treadle is depressed, six evenly spaced springs force the clutch jaws into mesh and ensure instantaneous engagement. At the end of the cutting stroke, the clutch is automatically disengaged and will not operate until the treadle is again depressed, unless the clutch is set for continuous running. The machine can be operated at 50 strokes per minute.

The standard gauge fitted to the machine has a fine adjustment to facilitate setting for parallel or angular cutting. A rear chute is fitted which allows the sheared material to fall clear of the machine and at the same time encloses the crankshaft, backshaft and connecting links. All other moving parts are also securely guarded. Also included in the standard equipment are a squaring guide, a starter and push button station, a finger guard and a lubricating gun.

Available as extra fittings are: a special micrometer type back gauge, which is operated by a handwheel through accurately cut screw-shafts; extra long front gauge brackets with support (5 ft. from the blade); an extra long squaring guide bracket with measuring rule and support (6 ft. from the blade); and special four cutting edge blades for cutting silicon steel and stainless steel.

Keeton, Sons and Co., Ltd., Keetona Works, Greenland Road, Sheffield, 9.

Small Induction Motors

A NEW range of small induction motors, from 1/40 h.p. to 1/10 h.p. and continuously rated to B.S. 170 : 1939, is announced by The General Electric Co., Ltd. Rolled steel shells with pressed-in wound stator cores form the motor bodies, with aluminium pressure-cast bearing brackets spigoted into each end. Sleeve bearings, diamond-bored true with the bracket spigot, are fitted as standard, and oil-saturated felts provide efficient lubrication for prolonged running without re-oiling. The squirrel cage rotors, cast in aluminium, are dynamically balanced and fitted with an accurately ground high-grade steel shaft. Connection leads are brought out external to the motor. All motors are electrically reversible and connection details are provided with each machine. An arrangement of thrust washers at the opposite driving end bearing permits the motors to be run in any position.

The motors are available either as capacitor start and run or split-phase. The capacitor start motors develop moderate starting torque, have good overload capacity, and are particularly suitable when starting conditions may be prolonged. These motors are provided with continuously-rated impregnated paper capacitors in welded oval aluminium cans for separate mounting. The split-phase motors, recommended where a higher starting torque is required and the load permits rapid acceleration to full speed, are supplied with separately mounted current-operated relays in moulded cases. The single phase 50 c./s. motors are available in standard voltage ranges: 200/220 V., 230/250 V. and non-standard 100/110 V. They are available for foot, resilient base, resilient cradle, or, flange mounting.

The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

Magnetic Particle Coupling

AN electromagnetic form of drive coupling, claimed to have the resilience of its fluid flywheel counterpart with the stability of a solid device, has recently been introduced by S. Smith & Sons (England), Ltd. It is a constant torque unit, the torque being independent of speed, and has a safety feature permitting a certain amount of slip when necessary.

Briefly, the coupling contains two rotors, one within the other, but separated by an air gap containing a quantity of ferro-magnetic powder: to one of the rotors is coupled the input shaft, and to the other the output shaft. Around the two rotors is a stationary field member containing an exciting coil, with an air gap between it and the input rotor. When current is applied to the coil, magnetic flux is created which crosses the air gap between the stationary member and the input rotor, and the powder gap between the input and output rotors. When the flux passes through the powder, the particles are attracted between the pole faces in such a way that torque, or turning force, proportionate to the degree of

excitation is transmitted from the input to the output rotor.

Thus, in the magnetic particle coupling, tangential forces are being transmitted in the working air gap between the inner and outer rotors through the ferro-magnetic powder medium. This medium, which is dependent on the magnetic flux density in the air gap, can be usefully compared to a hydraulic fluid where the viscosity is controllable and infinitely variable. This is of paramount importance, as it gives the magnetic particle coupling unique qualities. During the take-off period, the coupling operates with a smoothness and an absence of jerk or judder met only in hydraulic devices. On the other hand, under full excitation, the coupling will become solid, there being no slip, and therefore no generation of heat and no loss of efficiency. The dynamic and static coefficients of friction are equal.

By its nature, this coupling is ideally suited to automation. The consistent relationship between output torque and excitation current values from a static condition up to a locked-in condition makes it most suitable for control from a sensing device which is associated with the process under consideration.

The magnetic particle coupling is available in torque capacities ranging from $\frac{1}{2}$ to 200 lb. ft., and operates from 24 or 180V. D.C. as standard, though special voltages can be catered for. Power consumption varies according to size: for the 50 lb. ft. coupling it is 72W.

S. Smith & Sons (England), Ltd., Industrial Products Department, Witney, Oxon.

Honeycomb Bond Check

A NEW method for checking the bond in honeycomb structures, known as Bondcheck, has been developed by the Magnaflux Corporation, Chicago. The Bondcheck BC-1 inspection kit is used most successfully on metallic honeycomb, soldered, welded or brazed to the skin surfaces. The test procedure begins by cleaning the part surface and then spraying on a specially formulated red fluid that is repelled by heat and tends to flow to the coolest area on a metal surface. Next, a controlled heat is applied from a high intensity infra-red lamp. This heat is conducted from the surface being inspected to the honeycomb core wherever good bond exists between the core and the surface. Since the visible fluid flows to the coolest areas, it accumulates at every point of good bond, reproducing an exact pattern on the bonded area. Areas of defective bond are visible as gaps in this pattern. Deformed core materials are also readily apparent with the inner core pattern visible in the outer surface pattern. The test takes only a few seconds per area tested and any complex shape can be tested: automatic testing is practical on simple shapes.

The BC-1 Bondcheck kit consists of two separate carrying cases. Case No. 1 contains an inspection stand, spray gun, 25 ft. air hose, air pressure regulating valve, air gauge and filter, one quart of Bondcheck fluid, and two 12 oz. spray cans of cleaner. Case No. 2 houses the powerstat, which enables the inspector to vary the heat intensity: this device operates on 110 volt, 60 cycle, single phase current, drawing up to approximately 15 amp. Correct technique and proper timing are required for accurate results in regular production use.

Magnaflux Corporation, 7300 West Lawrence Avenue, Chicago 31, Illinois, U.S.A.

Electronic Temperature Controller

THE Sifam Pyromaxim electronic temperature controller has been designed to satisfy the demand for an accurate, sensitive and reliable controller at a reasonable price. It is available in ranges from 0–200° C. to 0–1,600° C., and calibration can be made for any type of thermocouple, a wide variety of which are made by Sifam. Automatic cold junction compensation is a standard provision.

The measuring galvonometer has a powerful Alcomox magnet surrounding a moving system which swings between spring mounted sapphires. The movement and its pointer are completely free of mechanical stress or interference. A simple electronic circuit provides the link between measurement and control, which instantaneously operates an enclosed relay rated at 3A. and 250V. A.C. non-inductive load.

A notable feature of the instrument is the plug-in arrangement of the electronic amplifier unit, which can be removed and replaced in a few minutes, thus facilitating maintenance. The Pyromaxim is available in hammer grey or matt black stove enamel finishes and with flush or wall-bracket mounting fittings.

Sifam Electrical Instrument Co., Ltd., Leigh Court, Hr. Lincombe Road, Torquay.

Improved Galvanised Sheet

THE formation of white rust on galvanised steel sheets has presented something of a problem since the early days of galvanised sheet manufacture, and substantial financial losses have been suffered due to the formation of white rust during shipment and storage. White rust appears on galvanised sheets when they have been exposed to unsuitable conditions, especially those giving rise to moisture on the surface of the sheets. The ultimate result is the destruction of the protective coating of zinc.

John Summers and Sons, Ltd., have now develpoed a process to reduce if not entirely eliminate the trouble. The new process is included as part of the manufacturing procedure in the production of Galvatite, a galvanised steel sheet product which will be supplied on all future orders. The technique has been developed by Summers' own research team, and it does not diminish the brilliance of the sheet surface, nor reduce the spangle. Before

claiming success for this new development, the Company carried out extensive tests, in one of which sample sheets of Galvatite were sent by sea to New Zealand and back. In the course of this journey they encountered considerable changes in temperature and weather, but returned to this country in perfect condition, without any signs of white rust formation, in marked contrast to a set of sheets of ordinary galvanised steel which accompanied them.

John Summers and Sons, Ltd., Hawarden Bridge Steel Works, Shotton, Chester.

High Impedance Recorder

DETAILS are now available of the new high impedance potentiometric recorder which was shown for the first time at the I.E. & A. Exhibition by Sunvic Controls, Ltd. It is a specialised version of the Sunvic RSP.2A single trace recorder to be introduced shortly, and production is, at the moment, allocated to the Company's nuclear instrumentation contracts. Designed for recording D.C. potentials of 0–100 mV. across an impedance not exceeding 10 MΩ, it has eight scale spans which can be altered by plug-in range bobbins.

The recorder has a calibration accuracy of $\pm 0 \cdot 05\%$ and sensitivity for a scale span of 15 mV. is :

Source Impedance	*Sensitivity*
300KΩ	$\pm 0 \cdot 1\%$
1MΩ	$\pm 0 \cdot 1\%$
5MΩ	$\pm 0 \cdot 15\%$
10MΩ	$\pm 0 \cdot 25\%$

A constant current supply unit with a stability $\pm 0 \cdot 1\%$ is incorporated for energising the measuring bridge circuit.

There are twelve chart speeds between 1 and 45 in./hr.; response is approximately 2 sec. for full scale deflection. Mains supplies can be 180–240 V. or 90–120 V., 40–60 c./s. High and low level alarm contacts, retransmitting slidewire or a Sunvic 300° shaft digitiser can be fitted.

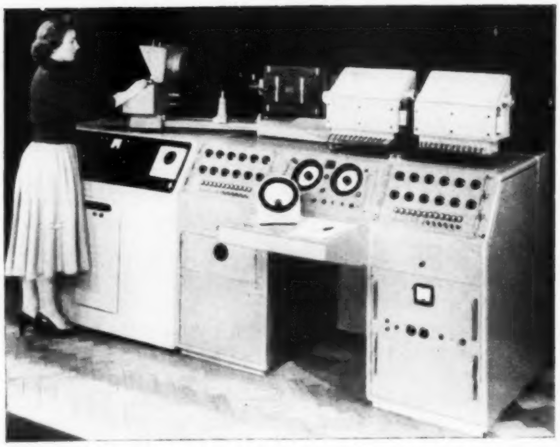
Range change and backing-off units have been designed for use with recorders monitoring ionisation current. The range change unit comprises a multi-point switch for selecting three independently adjustable values of resistance. Resistors are normally calibrated to give three decade ranges. The backing-off unit comprises a Kelvin Varley potentiometer, compensated to give a linearity of $0 \cdot 2\%$, and a constant current supply unit. It enables a standing ionisation current to be "backed-off" so that the recorder shows deviations from a desired current value.

Sunvic Controls, Ltd., 10 Essex Street, London, W.C.2

Hilger Triple Medium Spectrograph

THIS latest addition to the range of Hilger spectrographs will do all the work for which two instruments have hitherto been required. It is a photographic and direct-reading spectrograph combined, and will therefore be of particular use in laboratories where there is a large amount of routine work to be done, but where there are also some qualitative and quantitative analyses that fall outside the scope of the direct-reader.

As its name implies, it has three measuring heads. One of these is for photographic analysis and can be used for the same type of work as the well-known Hilger medium quartz spectrograph. The other two measuring heads



can be set up for the automatic analysis of non-ferrous metals, oils, soil, and similar materials. The spectrum required is chosen by switching mirrors.

Each direct-reading head accommodates twelve photomultipliers and will give quantitative analysis of up to eleven elements in about two minutes. These direct-reading heads can be set up for two completely different analyses (e.g., aluminium and magnesium alloys) or for the analysis of two different groups of elements in the same alloy (e.g., minor constituents and trace elements). For the latter application it is normal to use two separate sparkings—one for the minor elements using one bank of photomultipliers, and the other for trace elements using the other bank of photomultipliers—though in certain restricted circumstances, it is possible to analyse up to twenty-two elements with one sparking.

It is not necessary to buy both direct-reading heads at the same time. The instrument can be supplied in the first place with only one of these attachments and the second can be fitted at a later date, when required.

Hilger & Watts, Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1.

Mobile Crane

THE latest addition to the range of Jones diesel mechanical cranes, the KL 44B, is a modification of the highly successful KL 44. Advantage has been taken of the fact that the exceptionally high operating speeds of the KL 44, while important on such duties as grabbing, are not required by every operator needing a 4 ton capacity machine. By modifying these operating speeds, it has been possible to introduce a less powerful engine while maintaining the same lifting capacity, resulting in a considerable reduction in price.

With the KL 44B, the reduced hoisting speed in low gear with maximum load on two falls of rope is 22 ft./min., slewing speed 2 r.p.m. and top travelling speed, 3 m.p.h. The 4 ton maximum lift is handled at 8 ft. radius. Two wheel differential is standard, but direct drive models are available if required. The superstructure is mounted on an all-steel wheeled chassis, the patented steel restrictor wheels having heavy duty pneumatic tyres fitted as standard. Up to three crane motions can be operated simultaneously—slew through 360°, hoist or lower with maximum loads, and derrick

or travel, as selected. The crane's manoeuvrability and its ability to turn inside a tight circle allows it to work in confined spaces and at awkward angles. A variety of jibs, both straight and swan neck, and sufficient power to travel under load over difficult ground at extreme outreach makes the Jones 4 ton cranes extremely versatile.

K. and L. Steelfounders and Engineers, Ltd., Letchworth.

Heavy Duty Propane Regulator

A NEW propane regulator (Type P.R.1), recently introduced by British Oxygen Gases, Ltd. (Industrial Division), is a heavy duty, single-stage regulator which is suitable for propane and other liquid petroleum gases which are used for heating and cutting applications. The regulator has been specially developed for use in steel works, shipbuilding yards and heavy engineering works generally, where its simple, robust construction will enable it to withstand heavy wear and tear. The maximum outlet pressure of the regulator is 30 lb./sq. in., and the maximum flow rate approximately 300 cu. ft./hour.

British Oxygen Gases, Ltd., Spencer House, St. James's, London, S.W.1.

Dry Bearings

SINCE the introduction of the dry bearing by The Glacier Metal Co., Ltd., some three years ago, it has been adopted for applications in most sectors of engineering industry. The company recently announced three new developments in this field, the first of them, DU, providing three times the load/speed carrying capacity of the original DP material which it now supersedes. It comprises thin steel strip with a porous bronze coating impregnated with a mixture of fluoro-carbon plastic (P.T.F.E.) and lead. A stock range of bushes, thrust washers and flat strip is available for manufacturers wishing to conduct their own experiments.

The other new developments are DQ and DM. The former is a fluoro-carbon (P.T.F.E.) strengthened with special fillers and supplied in bar and tube form : non-standard or irregularly shaped dry bearings can be simply machined from this material. DM is a process for applying an adherent layer, about 0·0015–0·0025 in. thick, of a combination of fluoro-carbon and molybdenum disulphide to the bearing surfaces of customers' parts sent to Glacier for treatment.

All these new materials incorporate the Fluon brand of polytetrafluoroethylene supplied by Imperial Chemical Industries, Ltd.

The Glacier Metal Co., Ltd., Alperton, Wembley, Middlesex.

Infra-Red Projector

METROPOLITAN-VICKERS have just introduced an improved version of their standard infra-red projector. These projectors, which incorporate tubular metal-sheathed heating elements, are designed for general infra-red heating applications such as paint stoving, moisture extraction and preheating. They can be fitted end-to-end to form continuous troughs, assembled in banks, or used in angular formation to accommodate products of irregular shape. They can also be built into an enclosed plant, or used as robust portable units on stands. The end and back covers can be dispensed with where close spacing is desirable, such as in enclosed ovens. These covers in the new model are robust steel pressings with ventilation louvres instead of perforations.

Methods of supporting the projectors have been simplified : pressed steel brackets, readily clipped into slots, enable the units to be attached to 1-in. diameter conduit or bar. Alternatively, the slots can be used to bolt the projectors to angle or slotted angle. Conduit entry is catered for by a new type of fixing plate enabling the conduit to be attached by means of lock nuts.

The anodised aluminium reflector and metal-sheathed element remain unchanged, apart from an improved method of supporting the element in the reflector. Terminal arrangement has been improved by the use of nickel-plated steel bars in place of copper rod, and a simple arrangement allows the projector to be converted for use on D.C., single or 3-phase A.C. supplies.

Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

Slotted Angle

IT is claimed for the new version of Dexion 140 slotted angle that strength has been increased and rigidity improved, and that the new angle has a substantial price advantage over other types of slotted angle in this size, and will be used in a wide number of applications where previously a larger and more costly angle was required. The existing type 140 will no longer be produced. This incorporated a series of slots, each approximately 1 in. long, running parallel to the heel of the angle ; these have now been removed, leaving a wide solid strip of metal in the middle of the angle and thus introducing extra strength.

Another important development will be the inclusion of 20 new-type cornerplates in each packet of Dexion new 140 steel. These will provide new standards of rigidity which are particularly desirable in steel structures. The design of these cornerplates includes what might be termed a self-locking feature. When the cornerplate is fixed in position, it permits movement in one vertical plane only and, as the cornerplates will always be fixed in pairs—at both ends of a beam, for example—perfect locking can be achieved.

New Dexion 140 bolts effectively to Dexion 225 and 300 slotted angles, and like all other Dexion slotted angles, is available in aluminium alloy as well as steel.

Dexion, Ltd., Maygrove Road, London, N.W.6.

Tapping Fluid

A NEW tapping fluid has been introduced by Amber Oils, Ltd. Known as A.P. Cutting Fluid, it is an extreme pressure coolant with unusual penetration properties. It was originally produced for tapping armour plating, but has since been found to be outstandingly good for tapping all very high tensile materials, including the Nimonics, etc.

A large aircraft manufacturing firm reports that, when tapping S.99 and S.110 using A.P. Cutting Fluid, they were able to make each tap last several days per regrind, and breakages were eliminated. It is claimed that the saving in tool costs and production delays which can be achieved by the use of A.P. Cutting Fluid in such special circumstances, more than offset its high cost.

Amber Oils, Ltd., 11a Albemarle Street, London, W.1.

CURRENT LITERATURE

Book Notices

STATISTICAL SUMMARY OF THE MINERAL INDUSTRY, 1951–1956
(Production, Exports and Imports)

Prepared by the Mineral Resources Division, Overseas Geological Surveys. Royal 8vo., 371 pages. Published by Her Majesty's Stationery Office. 27s. 6d. net.

The Statistical Summary of the Mineral Industry is an annual publication of statistical tables covering a period of six years showing world production, exports and imports of all the important economic minerals and metals. This edition covers the period 1951 to 1956.

In the sections on copper, lead, tin and zinc, tables are given showing production of ore and metal. The ore tables give the metal content of the ore produced, whilst the metal tables record the amount smelted. So far as possible, the latter tables give the amount of primary metal obtained, showing separately, wherever important, production of secondary metal. Thus it is possible to see at a glance the amount of new metal available in any year.

The sections on coal and petroleum are very comprehensive, including statistics of the production and trade of by-products and refinery products. As the unit for these fuels is the same, comparison is facilitated. Statistics for all the principal non-metallic minerals are also included.

The summary contains a wealth of information on world exports and imports of minerals and metals, including not only the crude material, but complete details of the chief semi-manufactured products, refinery products and other derivatives.

SPECTROCHEMICAL ABSTRACTS
Volume V : 1952–1953

By E. H. S. van Someren and F. Lachman. Octavo, 66 pp. Published by Hilger & Watts, Ltd., 98 St. Pancras Way, London, N.W.1. 20s.

This, the fifth volume in the series, contains some two hundred and fifty abstracts of papers relating to emission spectroscopy in its analytical applications. Flame spectroscopy is included, but not X-ray emission spectroscopy. In the first part of the book, authors and the references to their papers are arranged alphabetically under authors' names, and this is followed by a list, for each element, of the papers in which that element has been observed as a minor constituent of a sample.

The remainder of the book is devoted to the abstracts themselves. These are divided into groups, according to their main interest, dealing with substances analysed, apparatus, methods, source theory, reviews, charts and tables, and books. The section on substances analysed is further sub-divided into biological materials, ceramics and slags, gases, oils, liquids, minerals, non-metallic solids, and metals and alloys. In preparing the subject index, the authors have selected the main subject of a communication and denoted it by a key word, using abundant cross references to ensure that papers dealing with several aspects are easily recognised. In the main, the classification headings of previous volumes have been preserved.

B.S.I. YEARBOOK

1958 edition. 520 pp., published by the British Standards Institution, 2, Park Street, London, W.1. 15s. plus 1s. 6d. postage and packing.

The total number of British Standards issued between B.S.I.'s foundation in 1901 and the end of last year, exceeded 3,000. This fact emerges from the recently published B.S.I. Yearbook for 1958, which includes a numerical list and brief descriptions of all standards current on 31st December, 1957.

With this and a wealth of other information, the Yearbook is the only available "reference book" to British Standards, and, as such, it is of great value to every user of them. Apart from British Standards and Codes of Practice, the 520-page book also lists the publications issued by the International Organization for Standardization (I.S.O.), the International Electrotechnical Commission (I.E.C.) and the International Commission on Rules for the Approval of Electric Equipment (C.E.E.) ; these publications are all available for purchase from B.S.I.'s Sales Branch. Other sections of the book detail a number of B.S.I. services, from the list of industries for which "sectional lists" of current standards are published, to the "approval services" provided for United Kingdom manufacturers who export to Canada. There is also a comprehensive index in which all British Standards are listed according to their subjects.

Translation Review

ISOTHERMAL TRANSFORMATION OF AUSTENITE

By A. Hultgren, K. Kuo and K. Tikkanen, *Jernkontorets Ann*, 1951, **135** (8), 403–494. Available as Translation No. 734 from the Co-operative Translation Service, The Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1 The price is £10 for the text only : the 105 illustrations can be supplied for an additional £3 10s.

When steel is cooled from the austenitic condition, at rates insufficient to produce martensite, it forms a series of structures consisting essentially of ferrite and carbides. The microstructure obtained is very sensitively dependent on cooling rate and on steel composition, and much work has been done on isothermal transformation to elucidate these structures and obtain information of practical interest in heat treatment. The present very lengthy paper gives in great detail the results of many years' work by Professor Hultgen and his colleagues, not so much on the kinetics of transformation as on the morphology of the products and its relation to kinetics.

Thus, ferrite may occur as a pro-eutectoid constituent, as one of the co-precipitating phases in pearlite, or as bainitic ferrite. The paper distinguishes two main types of ferrite, ortho-ferrite and para-ferrite, which are distinguishable metallographically and may form under any of the three main conditions, depending on temperature, composition and the nature of the other phase constituents present. Carbides, again, may form before the eutectoid, with it (as a pearlite constituent), or in the bainite. Not only do the authors distinguish between ortho and para-cementite, they also include cases where,

mainly because of alloy content, special carbides are formed.

In addition to numerous very striking micrographs supporting the sub-division of ferrite and carbide into these various categories, much chemical and X-ray analytical work, for which of course Dr. Kuo is already well known in this country, has been carried out on the carbides extracted from various specimens. The metallographic and analytical results throw much new light on the causes underlying the familiar C-or S-shape of the isothermal transformation diagram, and the effects on the diagram of alloy additions.

When originally presented in Sweden, the paper evoked a vigorous discussion, which the present translation includes in full. There is no doubt that its availability in English will provoke similar discussion among metallurgists interested in the subject.

Trade Publications

THE first leaf of a completely new section of the loose-leaf catalogue of Hilger scientific instruments has just been issued by Hilger & Watts, Ltd. It concerns synthetic crystals, and deals with thallium-activated sodium iodide, one of the most important phosphors for the detection and measurement of γ-radiation, which can be used in γ-ray spectrometry; and crystals of rocksalt and potassium bromide for use in infra-red spectroscopy.

WE have received from W. C. Holmes & Co., Ltd., a copy of Publication No. 71, which deals with the Type RB Holmes-Connersville range of roller bearing positive air blowers. The 10 in. machine has been manufactured for some time, but it has been redesigned to bring it into line with the recently introduced 12 in. model. Because neither internal lubrication nor sealing liquid is called for, the air delivered does not pick up oil, oil vapour, or excess moisture in the blower.

REMOTE handling equipment for atomic research work, electronic control gear, testing apparatus and special purpose machinery made by the Ayling Industries Group of companies are described in a new brochure available from the Group's sales organisation, the Ayling Nuclear Equipment Co., Horsham, Sussex. Apart from the English text, the brochure contains translations in French, German and Spanish and illustrates a number of the Group's products.

"NITROSO-R-SALT : a Reagent for the Determination of Cobalt and Iron" is the subject of a paper by Mr. R. J. Reynolds and Mr. P. Casapieri, which has been published recently by Hopkin and Williams, Ltd., as Monograph No. 33 in the series on organic reagents for metals. It can be obtained free from the company at Chadwell Heath, Essex.

WE have received from Monometer Manufacturing Co., Ltd., a publication dealing with oil and gas fired crucible furnaces manufactured by the company. These include hydraulic lip-pour tilting, central axis manually-operated and motorised tilting, lift-out and bale-out furnaces for melting non-ferrous metals.

"AN Experiment in Dust Control" is the title of an article in *The Brightside News* which deals with the successful efforts to deal with dust and fumes created in large quantities in the production of ingot mould castings. The problem was tackled jointly by the management of Brightside's Ecclesfield Foundry and the Research and Development staff of Brightside Heating and Engineering Co., Ltd.

IN low temperature thermal processes, heat transfer is mainly by convection, the radiation effect being negligible below 500° C. Because natural convection currents are sluggish, the rate of heat transfer is considerably increased by forced air circulation. A recent publication of Metalectric Furnaces, Ltd., Bulletin M 2B, gives details of the vertical air circulation furnaces made by the company.

WE have received from the Midland Saw and Tool Co. Ltd., Pamphlet No. M 13 covering the "Deep Throat" toolroom bandsaw. This is one of a number of pamphlets dealing with band sawing machines made by the company, and earlier pamphlets deal with "Minor," "Standard" and "Tridraulic" models.

WALKER, CROSSWELLER & CO., LTD., of Cheltenham have just issued a new comprehensive pamphlet illustrating their Arkon flow indicators. Incorporated are their very latest indicators (sizes ½–1 in.) which can be adjusted for high or low velocities of flow. Arkon indicators are used to show the flow of cooling water, lubricating oil, cooling oil, gas or air, etc.

REFRACTORY MOULDINGS & CASTINGS, LTD., have recently issued a new brochure (No. 238) dealing with refractory shapes. The company produces refractories to the specific requirements of the customer to any shape, size or practical tolerance, and particulars are given in the brochure of the various grades, based on molochite, sillimanite, silicon carbide, alumina, and zircon-zirconia. Reference is also made to composite or clad refractories.

PLATINUM and its alloys are widely used in heating elements for furnaces with working temperatures in the range 1,200–1,700° C., and the April issue of *Platinum Metals Review* features an article discussing the factors governing the design of such furnaces. Other articles deal with platinum-faced titanium; a new electrode material for impressed current cathodic protection; the importance of platinum in petroleum refining; the history of the melting of platinum; the structure of rhodium; and the development of metal-ceramics.

ISSUE No. 53 (April 1958) of *Redifon News Letter* features an article on the use of R.F. induction heating for chromising steel.

DEXION slotted angle is now widely used both in the laboratory and in the production department. An article in *Dexion Angle* (*No.* 9) illustrates the way in which this material has been used for supporting the 600 miles of single and multi-strand cable at The Steel Company of Wales' Velindre Tinplate Works.

Books Received

"Dislocations and Mechanical Properties of Crystals." Editors: J. C. Fisher, W. G. Johnston, R. Thomson and T. Vreeland, Jr. An International Conference held at Lake Placid, September 6th to 8th, 1956. Sponsored by Air Force Office of Scientific Research, Air Research and Development Command, and The General Electric Research Laboratory. 634 pp. New York and London, 1958. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 120s. net.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

JUNE, 1958. Vol. LVII, No. 344

The Determination of Tin and Tin-Iron Alloy Weights on Tinplate using the Kunze-Willey Method

By F. Cooke, B.Sc., A.R.I.C. and C. E. A. Shanahan, B.Sc., F.R.I.C., F.I.M.

Central Research Laboratories, Richard Thomas and Baldwins, Ltd.

Determinations by the Kunze-Willey method of tin and tin-iron alloy weights on tinplate agree satisfactorily with those obtained using chemical dissolution and weight loss methods, provided that a de-aerated electrolyte is used for the most precise work. The technique is rapid and accurate, and is ideal for the examination of differentially coated tinplate.

IN 1952[1] Kunze and Willey published a coulometric method for the determination of tin and tin-iron alloy on tinplate which is considerably more rapid than techniques embodying chemical dissolution of the coatings and weight loss measurements. The validity of the method applied to alloy determination has been confirmed by Hoare and Thwaites,[2] and it would appear to be ideal for the routine determination of coating weight.

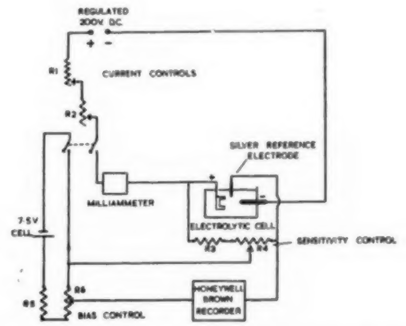
The form of the Kunze-Willey apparatus is such that it may be used for the determination of any coating which can be oxidised or reduced stoichiometrically, and when a perceptible change in surface potential is obtained on stripping. For example, it may be used to determine the amount of oxide coating on tinplate.

For the above reasons, an examination has been made of the Kunze-Willey method for the determination of tin and tin-iron alloy coatings on samples of both hot-dipped and electrolytic tinplate. Kunze-Willey results are compared with those arising from chemical stripping and weight loss measurements.

Experimental

Apparatus and Principle of Kunze-Willey Method

Kunze and Willey's method determines the free tin and tin-iron alloy by measuring the quantity of electricity required for their anodic dissolution in N-hydrochloric acid. The respective periods of dissolution of the two layers are determined from sharp changes in the continuous record of the potential developed between the specimen and a reference electrode when all the free tin has dissolved and when all the alloy has been removed. A schematic diagram of the basic circuit is given in Fig. 1 : it consists of a 200 V. D.C. electronically stabilised power pack (250 mA. current max.) feeding the electrolytic cell via two resistances R.1 and R.2 (current controls) and a milliammeter. The potential between the silver/silver chloride reference electrode and the tinplate anode is dropped across resistors R.3 and R.4 (sensitivity control), and a suitable voltage fed to the single pen recorder (Honeywell-Brown Electronik, chart speed 2 in./min.) by adjustment of R.4. The 7·5 V. cell and resistors R.5 and R.6 provide a biasing

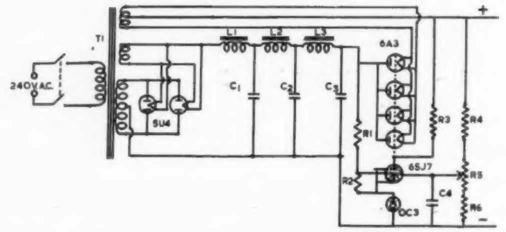


R1 8,000 ohms, 100 watts.	Low Range		R3 4,000 ohms, 2 watts.	Fixed
R2 500 ohms, 20 watts.			R4 200 ohms, 4 watts.	Variable
R1 1,500 ohms, 100 watts.	High Range		R5 6,800 ohms, 2 watts.	Fixed
R2 80 ohms, 50 watts.			R6 20 ohms, 4 watts.	Variable

Fig. 1.—Basic circuit.

voltage to give horizontal adjustment of the recorder pen. Details of the power pack, which is basically the same as that of Kunze and Willey, are given in Fig. 2, whilst the Perspex electrolytic cell is depicted in Fig. 3. The latter is a copy of the cell in use at the Tin Research Institute and requires no further comment, except to note that the purpose of the radially drilled holes in the tubular extension to the specimen holder is to facilitate uniform detinning of the sample.[2]

A determination is made by first mounting the 1·75 in. diameter specimen in the holder and electrolytically degreasing in 1% sodium carbonate solution, followed by thorough rinsing. The holder is then inserted into the electrolytic cell and with the current, sensitivity, and bias controls preset at suitable values, the recorder is switched on and the current allowed to pass through the cell until the recorder trace indicates completion of the stripping. The amount of free tin and tin-iron alloy are then calculated by Faraday's Law from the corresponding times of stripping, as derived from the potential changes on the recorder trace (see Fig. 4), using electrochemical equivalents of 0·615 and 0·507 mg./coulomb



L1, L2, L3	Filter choke. 10 Hy., 250 mA.		
C1, C2, C3	0·8 mfd. electrolytic. 500 V. D.C.		
C4	0·005 mfd., 600 V. D.C.		
T1	Power transformer. 550–0–550, 5 V.-3 A., 6·3 V.-2 A., 6·3 V.-5 A.		
R1	20,000 ohms, 10 watts.	R4	35,000 ohms, 1 watt.
R2	15,000 ohms, 10 watts.	R5	100,000 ohms, variable.
R3	470,000 ohms, 1 watt.	R6	180,000 ohms, 1 watt.

Fig. 2.—200 V. D.C. regulated power supply.

for tin and tin-iron alloy, respectively. Coating weights in mg./sq. in. are obtained by dividing the amount found by the stripped area of the specimen (1·76 sq. in.).

Results

The object of the investigation was to compare, as far as possible, tin and tin-iron alloy coating weights obtained by the Kunze-Willey method with those derived from chemical dissolution processes. Since the recommended stripping current varies (e.g. Kunze and Willey used a current density of *ca.* 60 mA./sq. in. for both free and alloy tin, while Hoare suggested *ca.* 20 mA./sq. in. for tin alloy alone) a further objective has been to assess the influence of stripping current on the accuracy of the method.

Experiments have been carried out on two types of tinplate, viz. 8 oz./b.b.* electrolytic and 20 oz./b.b. hot dipped. The two samples of tinplate were divided in 4 sq. in. specimens, identified according to the pattern shown in Fig. 5. Tin and tin-iron alloy were separately determined on both sides of the 4 sq. in. tinplate areas marked *H* by the Hothersall and Bradshaw method for free tin,[3] followed by the Clarke solution stripping method for the alloy. Kunze-Willey specimens were punched from the adjacent areas *K* and determinations carried out on both sides of the specimens. Current densities were varied between 20 and 110 mA./sq. in.

* The unit of area used by the tinplate industries is the "basis box" and is equivalent to an area of 31,360 sq. in. of tinplate. Since this is tinned on both sides the coating weight, normally expressed in oz. or lb. per basis box, is distributed over 62,720 sq. in.

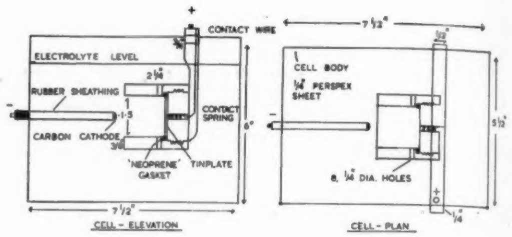


Fig. 3.—Electrolytic cell.

Details of the results and the specific currents used for each sample are presented in Tables I–III, whilst a summary of the mean values is given in Table IV. The gravimetric loss after stripping in the Kunze-Willey cell has been corrected in the latter table for the small amount of iron dissolved before switching off the stripping current. In all tables the term "free tin" refers to unalloyed tin; the tin in the tin-iron alloy is called "alloy tin," the sum of free and alloy tin is called total tin, whilst the free tin plus the tin-iron alloy is referred to as the "total coating." All figures are given as mg. coating/sq. in. of one side (1 oz./b.b. = 0·452 mg./sq. in.).

Discussion

A statistical analysis of the results for the 8 oz. tin-

TABLE I.—RESULTS OF COATING WEIGHT DETERMINATION ON THE FRONT SURFACE OF THE 8 OZ./B.B. ELECTROLYTIC TINPLATE.
(all coating weights are given in mg./sq. in. of each face).

Chemical Stripping Methods				Kunze-Willey						
Sample No.	Hothersall Free Tin*	Clarke Alloy Tin†	Total Tin‡	Sample No.		Free Tin	Alloy Tin	Total Tin	Total Coating	Gravimetric Loss of Kunze-Willey Specimen
H.1	2·86	0·58	3·44	K.1	70 mA. Total Current	3·06	0·50	3·56	3·67	3·75
H.2	3·00	0·44	3·44	K.2		3·03	0·48	3·51	3·62	3·96
H.3	3·07	0·62	3·69	K.3		3·38	0·36	3·74	3·82	4·15
H.4	2·92	0·64	3·56	K.4		3·13	0·44	3·57	3·67	3·75
H.5	3·02	0·52	3·54	K.5		3·06	0·47	3·53	3·64	4·15
H.6	2·97	0·52	3·49	K.6		2·98	0·50	3·48	3·60	3·96
H.7	3·05	0·52	3·57	K.7		3·15	0·42	3·57	3·67	3·71
H.8	3·04	0·52	3·56	K.8		3·08	0·50	3·58	3·70	3·75
H.9	2·97	0·49	3·46	K.9		3·15	0·47	3·62	3·73	3·85
H.10	3·04	0·69	3·73	K.10		3·04	0·52	3·56	3·68	3·71
H.11	3·07	0·68	3·75	K.11		2·91	0·52	3·43	3·55	3·71
H.12	2·97	0·58	3·55	K.12		3·08	0·40	3·48	3·57	3·85
H.13	3·09	0·40	3·49	K.13		2·97	0·52	3·49	3·61	3·71
H.14	3·10	0·58	3·68	K.14		3·06	0·52	3·58	3·70	3·93
H.15	2·98	0·50	3·48	K.15		3·06	0·48	3·54	3·65	3·93
H.16	3·03	0·52	3·55	K.16		3·06	0·48	3·54	3·65	3·96
H.17	3·00	0·68	3·68	K.17		3·01	0·59	3·60	3·74	3·75
H.18	—	0·52		K.18		3·06	0·53	3·59	3·71	3·85
Mean	3·01	0·56	3·57			3·07	0·48	3·55	3·66	3·85
H.19	3·04	0·58	3·62	K.19	35 mA. Total Current	3·07	0·57	3·64	3·77	3·75
H.20	2·92	0·56	3·48	K.20		3·04	0·57	3·61	3·74	3·85
H.21	3·03	0·59	3·62	K.21		3·04	0·57	3·61	3·74	3·93
H.22	3·04	0·63	3·67	K.22		3·01	0·55	3·56	3·69	3·96
H.23	3·10	0·68	3·78	K.23		3·04	0·58	3·62	3·76	3·64
H.24	2·97	0·78	3·75	K.24		3·01	0·57	3·58	3·71	3·93
H.25	3·00	0·64	3·64	K.25		3·06	0·45	3·51	3·62	3·75
H.26	3·00	0·68	3·68	K.26		3·08	0·45	3·53	3·64	3·58
H.27	3·14	0·52	3·66	K.27		2·98	0·55	3·53	3·68	3·54
H.28	3·10	0·52	3·62	K.28		3·01	0·55	3·56	3·69	3·54
Mean	3·03	0·62	3·65			3·03	0·54	3·57	3·70	3·75

* Unalloyed tin. † Tin in tin-iron alloy. ‡ Sum of free and alloy tin.

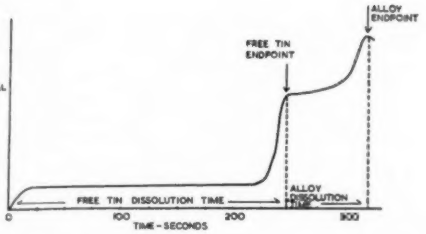


Fig. 4.—Potential-time recorder trace. 8 oz./b.b tinplate, 35mA. total current.

plate sample leads to the conclusion that there is a significant difference between

(*a*) the mean free tin values obtained by the Hothersall and Kunze-Willey (100 mA.) techniques,

(*b*) the mean alloy tin results by the Kunze-Willey method at 35 and 70 mA. currents,

(*c*) the mean alloy tin results derived by the Clarke and Kunze-Willey methods at both 35 and 70 mA.

Whilst the transition from alloy to base metal is always precisely marked on the potential-time trace, that from free tin to alloy is sometimes indefinite and appears to vary with the current density and the tinplate sample. In general, the best curves were obtained at 35 and 100 mA. on the electrolytic plate and at 100 and 150 mA. on the hot-dipped plate. The indefinite transition is particularly marked on the 8 oz./b.b. 70 mA. curves, and probably explains the differences in mean alloy tin values noted in (*b*) and (*c*) above, since an error of estimation of $\pm$ 3 sec. would lead to an error of approx. $\pm$ 9% in the alloy figure. The transitions at 35 mA., however, were always well defined, and in this instance the variation in the mean alloy tin values given by the Kunze-Willey and Clarke techniques is probably due to errors in the latter.

The Kunze-Willey grouped standard deviation about the mean free tin value on the 8 oz. plate is 0·10 mg./sq. in.—exactly the same as that derived from the grouped Hothersall data; whilst the Kunze-Willey grouped alloy tin standard deviation is 0·045 mg./sq. in.—appreciably less than the deviation of 0·10 mg./sq. in. derived from the Clarke method data. The variation in the Kunze-Willey alloy value is in close agreement with the estimated error of 0·2 oz./b.b. of alloy quoted by Hoare.[2]

Comparisons of the various techniques for free and alloy tin on the hot-dipped plate show no statistically significant differences; all the methods used are, therefore, satisfactory with this type of plate. In general, with both hot-dipped and electrolytic plate, good agreement is obtained between the Kunze-Willey data and that by the Hothersall and Clarke methods, although, as will be shown later, the Kunze-Willey free tin values may be slightly low.

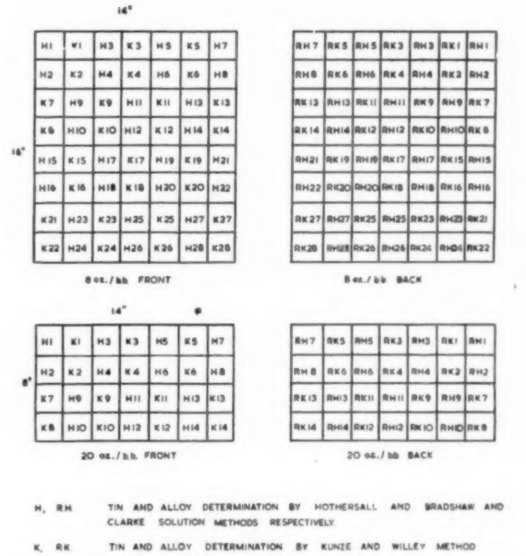


Fig. 5.—Sample pattern. 8 oz./b.b. and 20 oz./b.b. tinplates.

TABLE II.—RESULTS OF COATING WEIGHT DETERMINATION ON THE BACK SURFACE OF THE 8 OZ./B.B. ELECTROLYTIC TINPLATE.
(all coating weights are given in mg./sq. in. of each face)

Chemical Stripping Methods				Kunze-Willey						
Sample No.	Hothersall Free Tin	Clarke Alloy Tin	Total Tin	Sample No.		Free Tin	Alloy Tin	Total Tin	Total Coating	Gravimetric Loss of Kunze-Willey Specimen
RH.1	2·97	0·46	3·43	RK.1	100 mA. Total Current	—	—	—	—	—
RH.2	2·90	0·50	3·40	RK.2		3·22	0·51	3·73	3·85	4·09
RH.3	2·91	0·52	3·43	RK.3		3·15	0·49	3·64	3·76	3·87
RH.4	2·77	0·54	3·31	RK.4		3·15	0·51	3·66	3·78	3·92
RH.5	2·97	0·40	3·37	RK.5		3·17	0·49	3·66	3·78	3·81
RH.6	2·94	0·42	3·36	RK.6		3·15	0·49	3·64	3·76	3·75
RH.7	3·11	0·44	3·55	RK.7		3·11	0·49	3·60	3·72	3·75
RH.8	3·02	0·51	3·53	RK.8		3·07	0·51	3·58	3·70	3·81
RH.9	3·07	0·67	3·74	RK.9		3·11	0·51	3·62	3·74	3·92
RH.10	3·11	0·75	3·86	RK.10		3·07	0·54	3·61	3·74	3·85
Mean	2·98	0·52	3·50			3·13	0·50	3·63	3·76	3·86
RH.11	3·00	0·55	3·55	RK.11	35 mA. Total Current	3·16	0·45	3·61	3·72	4·09*
RH.12	3·00	0·53	3·53	RK.12		3·12	0·44	3·56	3·66	4·15
RH.13	2·89	0·58	3·47	RK.13		3·08	0·52	3·60	3·72	4·15
RH.14	3·00	0·60	3·60	RK.14		3·06	0·54	3·60	3·73	4·09
RH.15	3·02	0·52	3·54	RK.15		2·91	0·52	3·43	3·55	3·98
RH.16	3·05	0·52	3·57	RK.16		2·87	0·52	3·39	3·51	3·98
RH.17	2·95	0·46	3·41	RK.17		2·91	0·56	3·47	3·60	3·98
RH.18	2·89	0·52	3·41	RK.18		2·81	0·58	3·39	3·53	3·92
RH.19	2·90	0·42	3·32	RK.19		2·94	0·52	3·46	3·58	3·98
RH.20	2·87	0·42	3·29	RK.20		2·84	0·53	3·37	3·50	3·87
Mean	2·96	0·51	3·47			2·97	0·52	3·49	3·61	4·02

* This series of values was shown at the end of the run to be possibly in error because of the use of an additional 10 g. weight found to be 0·2 mg. high.

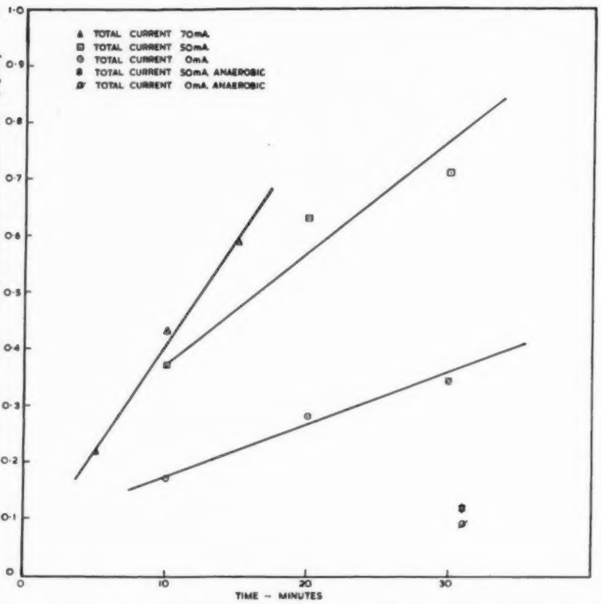


Fig. 6.—Dissolution of pure tin in Kunze-Willey equipment with normal and anaerobic electrolytes.

The calculated total coating weights (i.e. free tin plus tin-iron alloy) derived from the Kunze-Willey results should agree with the loss in weight of the specimens after applying a correction for the slight dissolution of the base steel. However, the weight loss values are significantly higher than the coating weights on four out of six runs.† A similar error was noted by Hoare; his values for free tin were lower than those obtained by Kunze and Willey using the same specimens. The variation appeared to result from the use of two different electrochemical equivalents; Hoare and Thwaites used the theoretical value, whilst Kunze and Willey derived their constant by calibrating the apparatus with pure tin specimens. This led Hoare to suggest that during the Kunze-Willey measurement, a small amount of tin dissolves without the passage of an equivalent quantity of electricity through the cell. The existence of this galvanic dissolution has been verified below.

† One 8 oz. 35 mA. run was omitted because of a possible error in the weights.

After establishing that the milliammeter (Sangamo-Weston sub-standard meter—accuracy ± 0·3%) and the recorder time scale were accurate to better than 0·5%, weighed samples of pure tin foil were inserted in the anode holder and allowed to remain in the electrolytic cell, using the normal electrolyte, for times varying from 10 to 30 min., either with no current passing or using total currents of 50 and 70 mA. The specimens were then re-weighed after rinsing with acetone and drying. Results are given in Table V, whilst Fig. 6 shows the differences between the calculated and observed weight losses plotted against the time of treatment. It is evident that galvanic dissolution of tin occurs, and that the amount of dissolution tends to increase with increasing current density. To confirm this, duplicate pairs of samples of tin foil were treated as above and then allowed to remain for 30 min., at zero and 50 mA. current, respectively, in hydrochloric acid de-aerated with nitrogen and through which nitrogen was allowed to bubble during the experiments. The means of the two sets of results are plotted in Fig. 6; after 30 min. exposure to the electrolyte, the weight losses are eight to ten times lower than those obtained under normal

TABLE III.—RESULTS OF COATING WEIGHT DETERMINATION ON THE 20 OZ./B.B. HOT DIPPED TINPLATE
(all coating weights are given in mg./sq. in. of each face)

Chemical Stripping Method				Kunze-Willey						
Sample No.	Hothersall Free Tin	Clarke Alloy Tin	Total Coating	Sample No.		Free Tin	Alloy Tin	Total Tin	Total Coating	Gravimetric Loss of Kunze-Willey Specimen
H.1	6·61	1·13	7·74	K.1		6·61	1·07	7·68	7·93	8·02
H.2	6·00	1·07	7·07	K.2		6·14	1·07	7·21	7·46	7·50
H.3	6·00	1·06	7·06	K.3	150 mA. Total Current	6·30	1·05	7·35	7·60	7·51
H.4	5·88	1·02	6·90	K.4		—	—	—	—	—
H.5	5·96	1·17	7·13	K.7		5·55	1·03	6·58	6·82	6·87
H.6	6·28	1·26	7·54	K.8		4·57	0·95	5·52	5·74	5·91
H.9	5·65	1·08	6·73	K.9		6·09	1·12	7·21	7·47	7·79
H.10	5·45	1·18	6·63	K.10		5·92	1·12	7·04	7·30	7·39
H.11	6·29	1·18	7·47	K.11		6·68	1·12	7·80	8·06	8·24
H.12	6·74	1·18	7·92	K.12		7·28	1·17	8·45	8·72	8·75
Mean	6·09	1·13	7·21			6·13	1·08	7·21	7·46	7·55
RH.1	7·06	0·90	7·96	RK.1		7·17	1·14	8·31	8·58	8·81
RH.2	6·68	0·99	7·67	RK.2		7·20	1·08	8·28	8·53	8·80
RH.3	7·63	1·16	7·79	RK.3		8·32	1·14	9·46	9·73	9·90
RH.4	8·18	1·23	9·41	RK.4		8·64	1·14	9·78	10·05	10·17
RH.5	8·18	1·29	9·47	RK.7	100 mA. Total Current	6·71	1·12	7·83	8·09	8·20
RH.6	8·87	1·22	10·09	RK.8		6·26	1·03	7·29	7·53	7·74
RH.9	6·97	1·16	8·13	RK.9		8·08	1·17	9·25	9·52	9·61
RH.10	7·22	1·07	7·29	RK.10		7·73	1·12	8·85	9·11	9·44
RH.11	8·44	1·13	9·57	KR.11		9·02	1·17	10·19	10·46	10·68
RH.12	8·28	1·07	9·35	RK.12		8·45	1·12	9·57	9·83	9·85
Mean	7·75	1·12	8·87			7·76	1·12	8·88	9·14	9·32
H.7	6·06	1·29	7·35	K.5		6·29	1·12	7·41	7·67	7·76
H.8	6·15	1·33	7·48	K.6		6·29	1·26	7·55	7·84	8·24
H.13	6·37	1·17	7·54	K.13		6·35	1·17	7·52	7·79	8·03
H.14	6·98	1·19	8·17	K.14	200 mA. Total Current	6·50	1·07	7·57	7·82	8·02
RH.7	8·44	1·35	9·79	RK.5		8·94	1·17	10·11	10·38	10·68
RH.8	8·54	1·33	9·87	RK.6		9·24	1·26	10·50	10·79	11·00
RH.13	8·65	1·23	9·88	RK.13		8·32	1·12	9·44	9·70	10·10
RH.14	8·30	1·13	9·43	RK.14		7·75	1·23	8·98	9·27	9·55
Mean	7·44	1·25	8·69			7·46	1·18	8·64	8·91	9·17

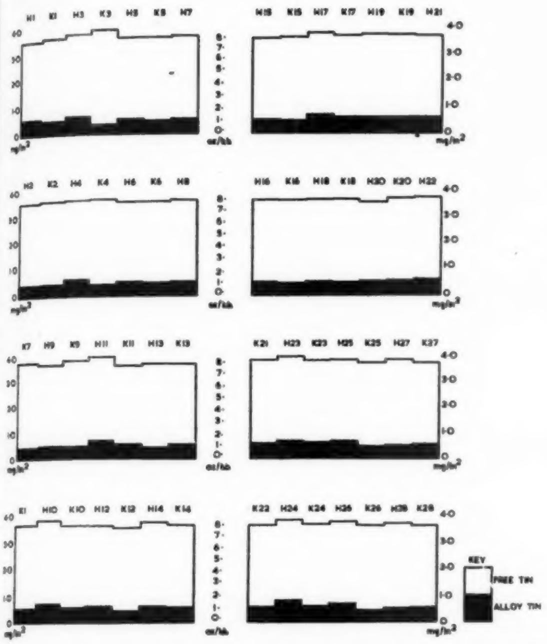


Fig. 7.—**Distribution of tin on 8 oz./b.b. electrolytic tinplate, along the direction of plating.**

aerobic conditions, showing that the depolarising action of dissolved oxygen causes galvanic tin dissolution.

It is estimated that the loss due to galvanic dissolution at 70 mA. total current is of the order 0·04 mg./sq. in./min. which would result in a maximum correction of approximately 0·1 mg./sq. in. to the free tin figure. This correction has not been applied to the present figures, since the content of dissolved oxygen in the electrolyte, which is the effective agent in the galvanic dissolution, may vary during a sequence of Kunze-Willey determinations, owing to the "gas washing" effect of the hydrogen evolved at the cathode. It does suggest, however, that the Hothersall values for free tin may diverge from the Kunze-Willey mean more than is indicated by the values in Table IV by approximately 0·1 mg./sq. in. The major point is that, when greater accuracy is required, de-aerated hydrochloric acid should be used in the electrolytic cell, which must then be fitted with a simple cover on either side of the anode holder, and nitrogen should be bubbled through the electrolyte during the determination.

The distribution of free and alloy tin on the electrolytic sheet, both along and transverse to the direction of plating, is shown in Figs. 7 and 8, respectively, whilst a similar distribution, on the hot-dipped plate transverse to the direction of tinning, is shown in Fig. 9. Because of the possible error in the determination of both free tin and alloy tin, the total error band on the total tin is approx. ± 0·3 mg./sq. in., and thus the observed variation in total tin may be due entirely to analytical error.

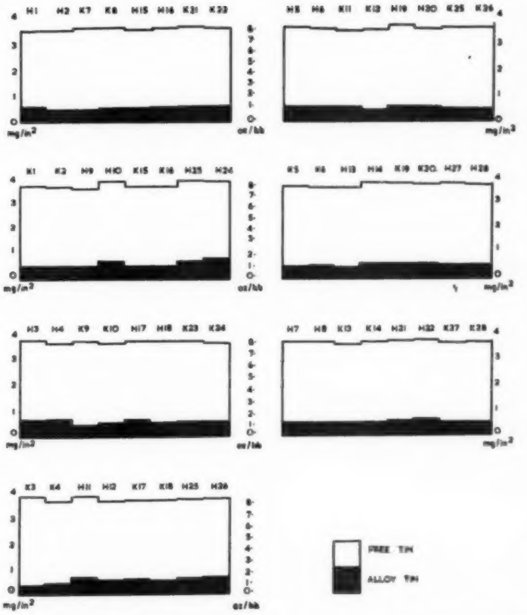


Fig. 8.—Distribution of tin on 8 oz./b.b. electrolytic tinplate, transverse to the direction of plating.

There is an apparent tendency for the alloy tin to vary with variations in the total tin. From the scatter diagram of free tin versus alloy tin (see Fig. 10) for the data used to prepare Figs. 7 and 8, it will be seen that the Clarke alloy results are in general higher than the

TABLE V.—DISSOLUTION OF PURE TIN DISCS WITH AND WITHOUT APPLIED CURRENT.

Electrolyte	Cell Current (mA.)	Immersion Time (min.)	Calculated Weight Loss (mg./1·76 sq. in.)	Observed Weight Loss (mg./1·76 sq. in.)	Weight Difference (observed-calculated)—(mg./sq. in.)
Normal	0	10	0	0·3	0·17
	0	20	0	0·5	0·28
	0	30	0	0·6	0·34
	50	10	18·45	19·1	0·37
	50	20	36·90	38·0	0·63
	50	30	55·35	56·6	0·71
	70	5	12·92	13·3	0·22
	70	10	25·84	26·6	0·43
	70	15	38·76	39·8	0·59
Anaerobic	0	30	0	0·2	0·09
	0	30	0	0·1	
	50	31	57·2	57·4	0·12
	50	31	57·2	57·4	

TABLE IV.—SUMMARY OF MEAN VALUES.
(all coating weights are given in mg./sq. in. of each face)

Tinplate	Free Tin		Alloy Tin		Total Tin		Total Coating			Kunze-Willey current mA.
	Hothersall method	Kunze-Willey	Clarke's Solution	Kunze-Willey	Hothersall Clarke	Kunze-Willey	Hothersall Clarke	Kunze-Willey	Gravimetric	
8 oz./b.b. Electrolytic (nominal total tin 3·62 mg./sq. in.)	3·03	3·03	0·62	0·54	3·65	3·57	3·76	3·70	3·71	35
	2·96	2·97	0·51	0·52	3·47	3·49	3·59	3·61	—	35
	3·01	3·07	0·56	0·48	3·57	3·55	3·70	3·66	3·81	70
	2·98	3·13	0·52	0·50	3·50	3·63	3·62	3·76	3·82	100
20 oz./b.b. Hot Dipped (nominal total tin 9·04 mg./sq. in.)	7·75	7·76	1·12	1·12	8·87	8·88	9·13	9·14	9·28	100
	6·09	6·13	1·13	1·08	7·22	7·21	7·48	7·46	7·56	150
	7·44	7·46	1·25	1·18	8·69	8·64	8·95	8·91	9·07	200

Kunze-Willey results, although the free tin values are comparable. The variable step effect of the alloy tin would thus be transmitted to the total tin contour, since the latter figure is the sum of the free and alloy tin. The distribution of alloy and free tin on the 8 oz. sheet is therefore uniform within the limits of experimental error.

Variation in the distribution of tin on the front of the 20 oz. hot-dipped plate is approximately ± 20% about the mean value of 7·4 mg./sq. in. (approximately 16 oz.): the coating weight on this side of the sheet is appreciably lower than that on the reverse side.

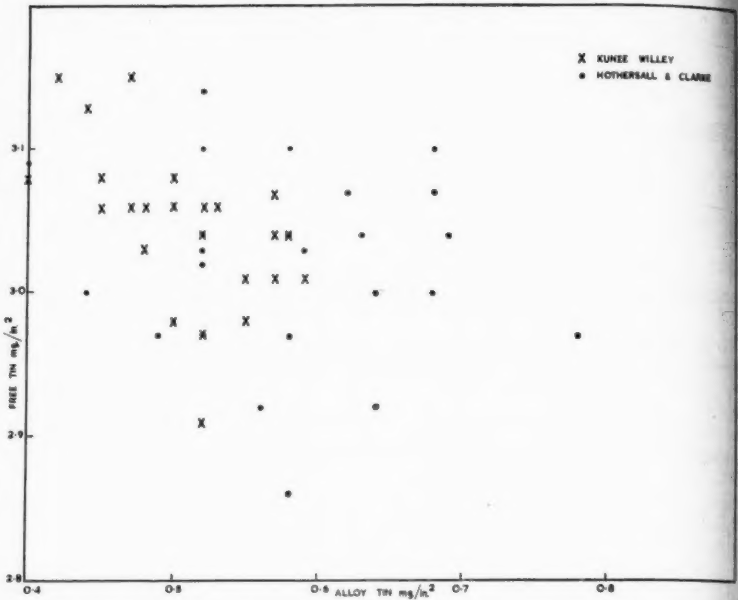


Fig. 10.—Comparative plot of free versus alloy tin on 8 oz./b.b. tinplate as determined by Kunze-Willey or Hothersall and Clarke methods.

Conclusions

(1) The Kunze-Willey method gives free tin values comparable to those obtained by the Hothersall method.

(2) Kunze-Willey alloy tin values are more precise than those derived by the Clarke solution stripping method.

(3) In view of the above conclusions and the rapidity of the Kunze-Willey technique, it is eminently suitable for routine determinations. Furthermore, since only one side of the specimen is used, the Kunze-Willey technique is ideal for the examination of differentially coated specimens.

(4) An inherent slight error exists in the Kunze-Willey technique due to galvanic tin dissolution. This effect can normally be neglected, but when precise results are required it is important to employ a de-aerated electrolyte. For routine use the equipment should be calibrated using pure tin discs.

(5) The probable accuracy of the Kunze-Willey method is ± 0·1 mg./sq. in. (0·2 oz./b.b.) in alloy and ± 0·2 mg./sq. in. (0·4 oz./b.b.) in free tin.

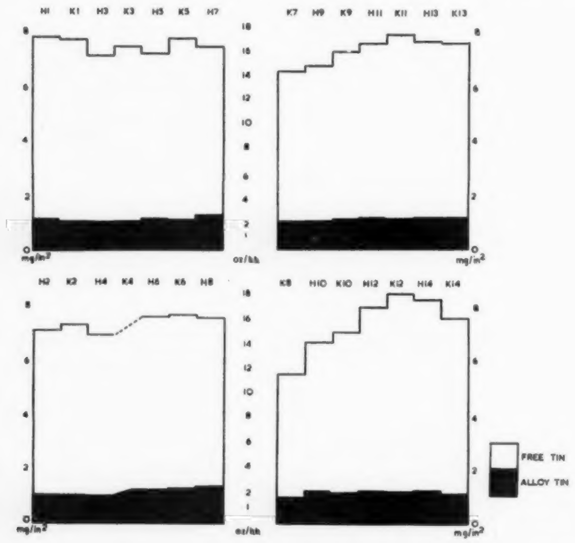


Fig. 9.—Distribution of tin on 20 oz./b.b. hot dipped tinplate, transverse to the direction of tinning.

Acknowledgment

The authors gratefully acknowledge the careful practical work performed by Messrs. J. Riley and P. Doarks. Thanks are due to Mr. R. A. Hacking, O.B.E., Director of Research of Messrs. Richard Thomas and Baldwins Ltd. for permission to publish this paper.

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Vitreous Enamelled Blackboards

The days of the old-fashioned blackboard are numbered. Schools all over the country may soon have enamelled chalkboards in their classrooms, instead of the traditional wooden board. A Wolverhampton firm, Ferro Enamels, Ltd., have now produced a specially-formulated enamel and applied it to sheet iron which in turn, is bonded to plywood or similar backing material. Known as Ferro chalkboard, it is a pleasant green colour with a matt finish and is claimed to be very restful to the eyes.

Being vitreous enamelled, the " board " is virtually indestructible and has the great merit that it is easily cleaned and does not lose its surface or colour, as do the more orthodox types of blackboard. Supplied with the chalkboards, which are manufactured to customers' requirements, are tiny magnets to fix papers or information sheets to the board when necessary. Already this new type of " board " has been installed at Wolverhampton Technical College, and other schools are expected to take them up shortly.

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